8th International Conference on Water Resources and Arid Environments (ICWRAE 8): 526-540
22-24 January 2019*, Riyadh, Saudi Arabia*

Transboundary River Water Management in South Asia: A Study of Indus Basin

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Abstract: Water sharing between India and its neighbours is a crucial issue. India's bilateral relations with its neighbours have been affected several times over this issue. Pakistan has been raising the issue of breach of Indus Water Treaty on every forum. Due to the rapid increase in population tremendous increase in demand of water has been observed for agriculture, industries and domestic requirements on both sides of the border. Agrarian economies of both the countries rely heavily on water resources. To ensure food and energy security both countries want to harness maximum amount of available water resources. Moreover, the scarcity of water is being accompanied by deterioration in the quality of available water due to pollution and environmental degradation. The aim of this paper is to study the transboundary water cooperation between India and Pakistan in the light of Indus Water Treaty. Relying on secondary sources of data, implications of post treaty development along with the environmental concerns and climate change has been discussed. This study concludes with the following suggestions to harness Indus water resource for the long lasting prosperity of the region; improve cross-border dissemination of hydrological and meteorological data and data sharing on precipitation trends to develop better water policy; implication of Geographical Information System (GIS) technology to analyse the proper status of water in the Indus Basin; introduction of agricultural practices which consume less water and new techniques of irrigation to prevent water loss; create awareness among the public of India and Pakistan regarding climatic change, its impact on environment, proper utilization of water, water harvesting, water recycling and water pollution.

Key words: Transboundary water・River Indus・India and Pakistan

INTRODUCTION

Water is a natural resource upon which all social and economic activities and ecologies depend. With unsustainable consumption and climate change threatening global water resources, UN declared 2013 International Year of Water Cooperation. Water being a part of a larger ecological system, its importance and scarcity must be realized, it has to be treated as an essential environment for sustaining all life forms. Water being a scarce and precious resource needs to be conserved and managed. It is one of the most crucial elements in developmental planning. Competition for water use intensifies with the increase in human demands for water leading to its scarcity over a period of time. Owing to various factors, the present era has been passing through a tough phase of water stress. Global economies are struggling to tackle the crisis of water shortage. This crisis eventually would lead to triggering serious conflicts inside and across the nations. The situation is even worse in case of utilization of transnboundary river water.

Water sharing between India and its neighbours has always been a crucial issue. India's bilateral relations with its neighbours have been affected several times over this matter. Pakistan has been raising the issue of breach of Indus Water Treaty on every possible forum. Due to the rapid increase in population, tremendous increase in demand of water has been observed for agriculture, industries and domestic requirements on both sides of the border. Agrarian economies of both the countries rely heavily on water resources and are struggling to ensure food and energy security for their growing needs. To ensure food and energy security both countries want

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Table 1: Country wise Area of Indus Basin

Basin	Area Km^2	Countries included	Area of country in basin (km^2)	As % of total area of the basin	As % of total area of the country
Indus	1 120 000	Pakistan	520 000	47	65
		India	440 000	39	14
		China	88 000	8	1
		Afghanistan	72 000	6	11

Source: FAO, Aquastat.

to harness maximum amount of available water resources. Moreover, the scarcity of water is being accompanied by deterioration in the quality of available water due to pollution and environmental degradation.

India and Pakistan share Indus river basin which is the 12th largest river basin in the world and India happens to be upper riparian. At time of the partition of Indian sub continent in 1947 the Indus basin was also divided. Soon after the settlement of boundaries between India and West Pakistan issue of water sharing emerged as major conflict. However India and Pakistan singed Indus Water treaty in 1960 to end the decade old water dispute. The treaty was signed as a permanent solution to the water sharing problem between the two countries. The Indus Water Treaty set a precedence of cooperation between India and Pakistan that has survived three wars and other hostilities between the two nations.

Stephen P. Cohen [1] has also observed that the Indus Waters Treaty is a model for future regional cooperation, especially on energy, environmental concerns and even the management of the region's impressive water resources. However, the Indus Water Treaty is continuously under stress in the recent past due to growing water scarcity in both India and Pakistan. Population growth, changing nature of agricultural practices, climate change, urbanization and industrialization on fast rate played a key role in making water scarce in the Indus basin. Water insecurity in the basin has further politicized the water issues. Hence sanctity of Indus water treaty has been questioned on multiple forums not only by the politicians and bureaucrats but also by the academicians and experts.

Keeping in focus this paradoxical nature of the treaty, which started as an 'ideal' form of collaboration is now moving towards 'possible conflict', the objectives of the present research and the whole gamut of problems revolve around the following issues;

- What kind of hydro climatic changes have occurred in Indus basin in the recent past?
- Which factors are responsible for water scarcity in the Indus basin?
- What is the mechanism of water sharing in Indus basin?
- What are the major issues of water sharing in Indus basin?
- How water issue is a significant matter impacting and influencing political, social and economic spheres of India and Pakistan relations?
- What could be the possible strategies for evolving cooperation rather than conflict in Indus basin?

Geography of Indus Basin: The Indus River was formed after the collision between the Indian and the Eurasian Plates 45 million years ago and is considered as one of the oldest documented rivers. Most of the upper drainage basin of the Indus River lies within the Karakoram with smaller parts within the Kohistan, Hindu Kush and High Himalaya Mountains. The Indus has occupied a relatively stable course throughout its history due to its location. It has deposited a considerable amount of alluvium in the Himalayan foreland basin and has built the huge alluvial plains. Over six millennia, the Indus River has been the source of water that supported the economy of the region, nurturing old and modern civilizations [2].

The Indus Basin is constituted by the waters of melting of ice, snow and the precipitation. The flow originates more from Indian territory as compared to Pakistan. However Pakistan has more basin area as compared to India in Indus basin. Table 1 explains the division of the total area of Indus Basin.

The Indus River rises in Tibet at an altitude of 5500m above mean sea level, in a catchment that contains some of the largest glaciers in the world outside the Polar Regions. The glacial area of the upper Indus catchment is about 2250 square kilometers and accounts for most of the river runoff in summer [3]. The Indus and its tributaries drain a total area of 115 Mha. The Upper Indus segment comprises its first 2145 km length, up to which point all significant tributaries meet. In the 735 km-long segment below, inflow is small. Out of the entire catchment area, the mountainous area totals around 44 Mha. In the first lap of the river course of 1,280 km up to Tarbela, five right-bank and three left-bank tributaries join. The total catchment up to Tarbela is about 17.5 Mha. Downstream of the Tarbela reservoir, the river reaches Attock traversing through a 64 km-long gorge. Below Attock, the river flows in a south-easterly direction for a total of 160 km to reach Kalabagh in the plains. The Indus River receives the waters of two left-bank and three right-bank tributaries in between Tarbela and Kalabagh. At Kalabagh Rim Station, the average annual flow is about 112 billion cubic metres (BCM). The river covers another 1,440 km from Kalabagh before joining into the sea. The basin's southern boundary extends up to the Arabian Sea. The eastern boundary is shared by India and Pakistan. The Indus plains consist of relatively flat tracts between the Indus and its major tributaries. The Indus system comprises 13 tributaries in hilly areas from the west and 14 in the plains [4].

Among the major tributaries Sutlej river originates in China in Western Tibet in the Kailas mountain range and near the source of the rivers Indus, Ganges and Brahmaputra. The river is 1536 km long and has a catchment area of 75369 square kms (of which 70 percent is in India). It flows into Pakistan (Punjab) near Ferozepur and eventually joins the Chenab river close to Punjnad barrage. The Ravi river originates in the lesser Himalaya's range in India. The river is 880 km long with a catchment area of 24960 square kms. It runs almost along the India Pakistan border. The Chenab river is formed at the confluence of the Bhaga and Chandra rivers, which join at a place called Tandi. Its uppermost part is snow covered and forms the northeast part of Himachal Pradesh. From Tandi to Akhnoor the river traverses high mountains. The river is 1232 km long and the catchment area is 41760 square kms. The river enters Pakistan a little over Head Marala with very sharp changes in slope. The Jhelum river originates in the Kashmir Valley, about 54 km east of Anant Nag and is 816 km long with a catchment area of 39200 square kms [5].

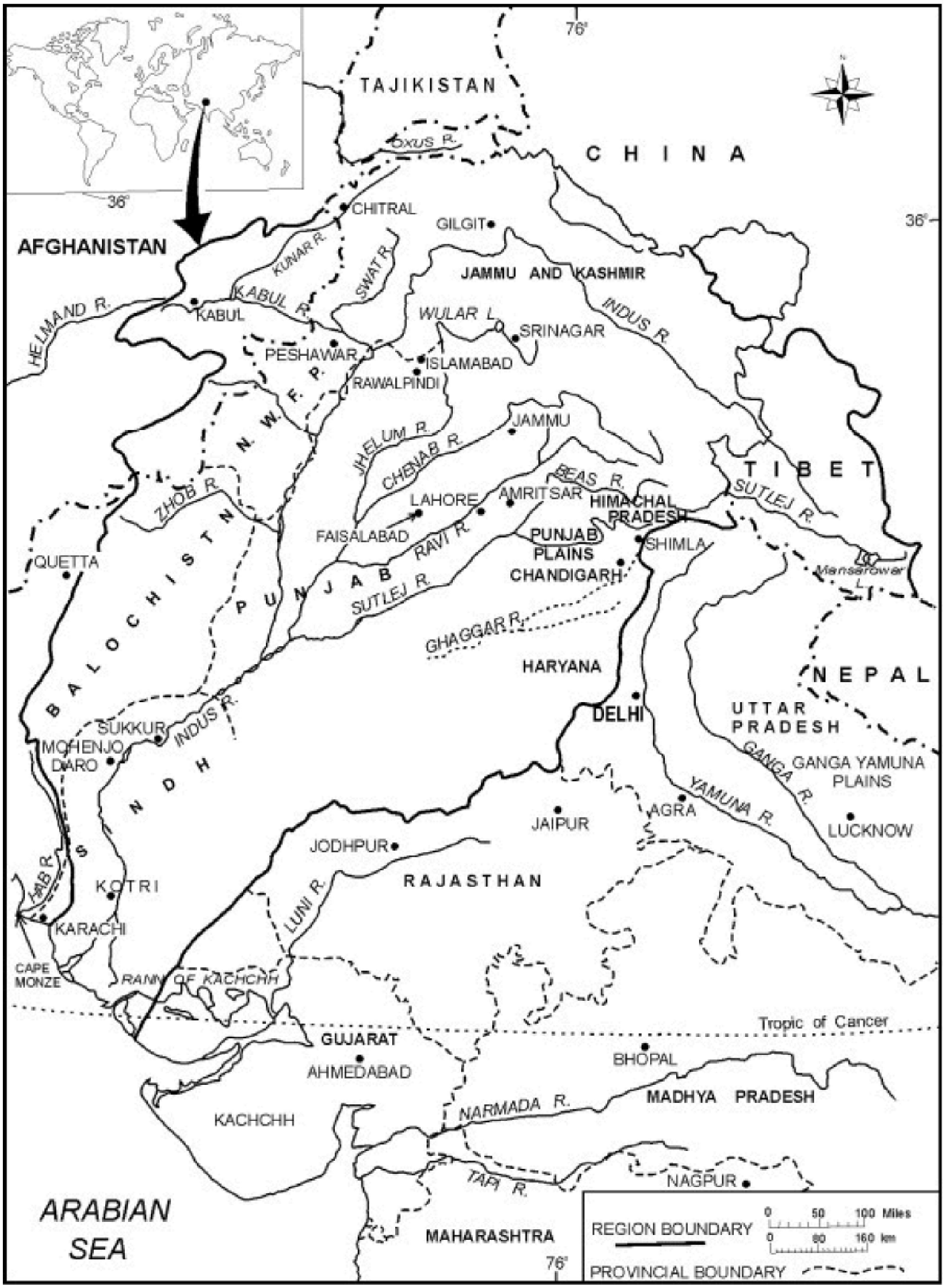
Groundwater has also acquired a pivotal role in the agricultural economy of India and Pakistan. Groundwater accounts for almost half of all irrigation requirements. Although, there is clear evidence that groundwater is being overexploited, yet tens of thousands of additional wells are being put into service every year both in India and Pakistan. Furthermore, there are serious and growing problems with groundwater quality, a reality that is likely to get worse in the coming years [6].

The Indus Basin rich in land and water resources is also full of variability and uncertainty in its climate and hydrology. Variability has also been observed in agricultural sustainability and food consumption of the Indus basin. Climate is not uniform over the Indus river basin. It varies from subtropical arid and semiarid to temperate sub humid on the plains of Sindh and Punjab provinces to alpine in the mountainous highlands of the north. Annual precipitation ranges between 100 and 500 mm in the lowlands to a maximum of 2000 mm on mountain slopes. Snowfall at higher altitudes (above 2500 m) accounts for most of the river runoff. The Upper Indus river basin is a high mountain region and the mountains limit the intrusion of the monsoon, the influence of which weakens northwestward. Most of the precipitation falls in winter and spring and originates from the west. Monsoonal incursions bring occasional rain to trans Himalayan areas but, even during summer months, not all precipitation derives from monsoon sources. Climatic variables are strongly influenced by altitude [7].

The supply of water stored in glaciers and snow is projected to decline globally during the 21st century. However, the patterns of depletion and accumulation vary regionally and locally. Variability in the distribution and timing of snowfall and changes in the melting of snow and ice, however, may be amplified by climate change and have implications for managing basin water resources. The remainder of the water availability after snow and ice melts in Indus basin is from the annual monsoon system. This contribution is even more variable than that of Upper Basin inflows. Finally, changes in temperature, precipitation and atmospheric carbon concentrations have a direct impact on water availability. Over the coming years such changes may pose major challenges for water managers. Managing groundwater resources continues to be another major challenge in the Indus Basin. Water logging and salinity in Indus basin have also been major concerns over the past century since the expansion of canal irrigation [8].

Water Scarcity in Indus Basin: Total annual requirement of fresh water for India for various sectors including agriculture, industrial, hydropower, domestic and other uses is estimated to be about 694 to 710, 784 to 850 and 973 to 1,180 km^3 by the years 2010, 2025 and 2050 respectively depending on the low and high demand scenarios (Table 2).

National Institute of Hydrology estimates show that this demand will be met by harnessing 700 cubic kilometres of surface water and 350 cubic kilometres of ground water. The average annual precipitation received in India is 4,000 cubic kilometres, out of which 700 cubic kilometres is immediately lost to the atmosphere, 2,150 cubic kilometres get soaked into the ground and 1,150 cubic kilometres flows as surface runoff. The annual water availability in terms of utilizable water resources in India is 1,122 cubic kilometres. The per capita availability of utilizable water, which was about 3,000 cubic metres in the year 1951, has been reduced to 1,100 cubic metres in 1998 and is expected to be 687 cubic metres by the year 2050 (Fig. 1).



Map 1

Source: Thatte C D (2008), Indus Waters and the 1960 Treaty Between India and Pakistan.

Table 2: Annual Water Requirement for Different Uses in India (in km³)

Uses	Year 1997-98	Year 2010 Low	Year 2010 High	Year 2010 Percent*	Year 2025 Low	Year 2025 High	Year 2025 Percent*	Year 2050 Low	Year 2050 High	Year 2050 Percent*
Surface Water										
Irrigation	318	330	339	48	325	366	43	375	463	39
Domestic	17	23	24	3	30	36	5	48	65	6
Industries	21	26	26	4	47	47	6	57	57	5
Power	7	14	15	2	25	26	3	50	56	5
Inland Navigation		7	7	1	10	10	1	15	15	1
Flood Control		-	-	0	-	-	0	-	-	0
Environment (1) Afforestation		-	-	0	-	-	0	-	-	0
Environment (2) Ecology		5	5	1	10	10	1	20	20	2
Evaporation Losses	36	42	42	6	50	50	6	76	76	6
Total	399	447	458	65	497	545	65	641	752	64
Ground Water										
Irrigation	206	213	218	31	236	245	29	253	344	29
Domestic	13	19	19	2	25	26	3	42	46	4
Industries	9	11	11	1	20	20	2	24	24	2
Power	2	4	4	1	6	7	1	13	14	1
Total	230	247	252	35	287	298	35	332	428	36
Total Water Use										
Irrigation	524	543	557	78	561	611	72	628	807	68
Domestic	30	42	43	6	55	62	7	90	111	9
Industries	30	37	37	5	67	67	8	81	81	7
Power	9	18	19	3	31	33	4	63	70	6
Inland Navigation	0	7	7	1	10	10	1	15	15	1
Flood Control	0	0	0	0	0	0	0	0	0	0
Environment (1) Afforestation	0	0	0	0	0	0	0	0	0	0
Environment (2) Ecology	0	5	5	1	10	10	1	20	20	2
Evaporation Losses	36	42	42	6	50	50	6	76	76	7
Total	629	694	710	100	784	843	100	973	1,180	100

Source: http://www.nih.ernet.in/rbis/india_information/AnnualWaterRequirements.htm
*Percent of the total high water required

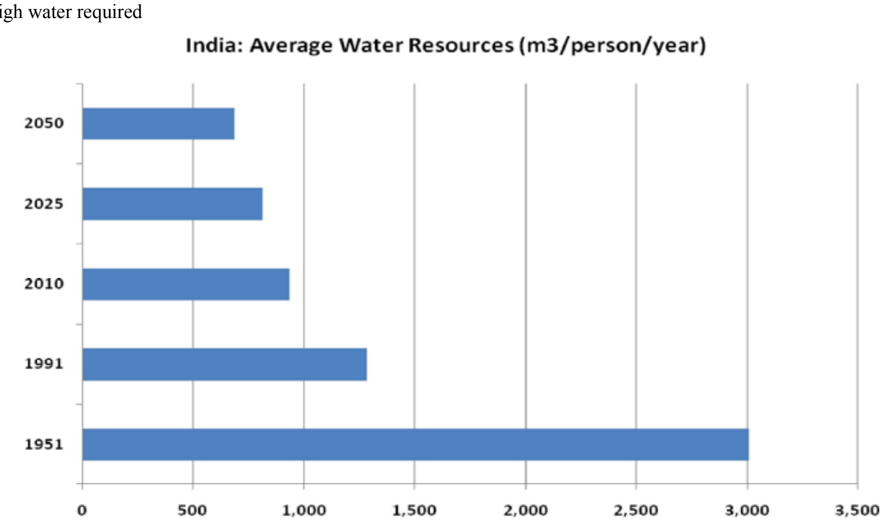


Fig. 1: Per Capita Availability of Water Resources in India
Source: http:// www.nih.ernet.in/ rbis/ india_information/ AnnualWaterRequirements.htm

Table 3: Renewable Water Resources and Withdrawal Levels in the Indus River Basin

Indicators	India	Pakistan
Average long-term available renewable water supplies in the IRB	97 km3/year	190 km3/year
Estimated renewable surface water supplies in the IRB	73 km3/year	160-175 km3/year
Estimated renewable groundwater supplies in the IRB	27 km3/year	63 km3/year
Estimated total water withdrawals in the IRB	98 km3/year	180-184 km3/year
Estimated total surface water withdrawals in the IRB	39 km3/year	128 km3/year
Estimated total groundwater withdrawals in the IRB	55 km3/year	52-62 km3/year

Source: Connecting the Drops: An Indus Basin Roadmap for Cross-Border Water Research, Data Sharing and Policy Coordination (2013), Observer Research Foundation, Stimson and Sustainable Development Policy Institute.

Similarly various national and international reports on Pakistan's water situation indicate that the country is fast moving from water-stressed to water-scarce. Pakistan Strategic Country Environmental Assessment Report (2006) underlines water availability per person has drastically fallen from about 5,000 cubic meters in 1947 to 1,100 cubic metres. It projects that water availability will hit below 700 cm per capita by 2025. Similarly, The Economic Survey of Pakistan (2009-10) assessed 1,066 cubic metre per capita availability of water in the country. Currently Pakistan's water requirement from the Indus Water system is 139.54 Million Acre Feet (MAF) while availability is 135.60 MAF [9]. Pakistan's economy depends largely on the water from the Indus Basin. The Indus Basin Irrigation System is the largest infrastructural enterprise, accounting for US $300 billion of investment and contributing US $18 billion (over 21 percent) to Pakistan's GDP during 2009–10. Irrigated agriculture provides 90 percent of wheat and food grains and nearly 100 percent of sugarcane, rice, cotton, fruits and vegetables. It also provides milk, meat and fuel-wood in addition to crops [10].

Water related data has always been juggled and utilized for political considerations for arriving at a decision. For example, the figures India and Pakistan each presented for irrigable areas in the Indus Basin differed considerably. India believed the total irrigable land in the Basin to be 65 million acres, with 26 million acres in India and 39 million acres in Pakistan. Whereas Pakistan estimated that there were 82.4 million acres in total with, only, 7.6 million acres in India and the remaining 74.8 million acres in Pakistan. The obvious reason for this huge difference can be understood only in the political domain. With its figures India was trying to demonstrate to the World Bank that its need for the Indus waters was equal to that of Pakistan. While Pakistan was desperate to illustrate its complete reliance upon the Indus Basin [11].

The available renewable water supplies in the Indus Basin average 287 km^3 per year, representing 190 km^3 of annual renewable water resources in Pakistan and 97 km^3 in India. The surface water accounts for around 73 km^3 for India and 160-175 km^3 for Pakistan, whereas, annual renewable groundwater supplies have been estimated at 90 km^3, reflecting resources of 27 km^3 in India and 63 km^3 in Pakistan. India withdraws about 98 km^3 yearly, with around 55 km^3 of withdrawals coming from groundwater stocks and 39 km^3 from surface sources. Pakistan's annual water demands from the Indus add up to 180-184 km^3, with 128 km^3 from surface water and 52-62 km^3 pumped from groundwater aquifers (Table 3).

The growing water stress in India and Pakistan is shaping the discourse on water between the two countries. The increase in water stress in the two countries has also put strain on the Indus Water Treaty. This debate is mainly driven by the growing demand, decrease in availability of water resources and degree of their dependence on the transboundary water resources.

Impact of Climate Change on Indus Basin Hydrology: The Indus originates in the Himalayas in the north and extends to the dry alluvial plains of Sindh Province in Pakistan in the south, finally draining into the Arabian Sea. The major part of the basin lies in arid-to-semi-arid climatic zones with considerable temporal and spatial climatic variation across the basin. Short spells of heavy precipitation occur in the summer (June to September), while westerlies bring precipitation in the winter and spring. After analysing precipitation trends in upper Indus basin Archer and Fowler [12] suggested a statistically significant increase in annual precipitation at several stations with an upward trend in winter rainfall at all stations north and south of the Himalayan divide and a statistically significant increase in summer rainfall at stations north of the Himalayan divide. It was unclear whether the latter was due to increased incursions of the monsoon or a stronger influence of the westerlies [13].

The temperature trends reported in the Indus Basin are not homogeneous. Fowler and Archer [14] reported a consistent lowering of mean and minimum summer temperatures, but no consistent trend in maximum summer temperatures, between 1961 and 2000. Similarly, Khattak *et al*. [15] also reported an increase in winter maximum temperatures between 1976 and 2005 in the upper, middle and lower parts of the Indus Basin. Chaudhry and Rasul [16] identified a significant increase in annual mean temperature in Balochistan, Punjab and Sindh Provinces in Pakistan between 1960 and 2007 of 1.15, 0.56 and 0.44 8C, respectively. They also observed an increasing but not significant trend in annual mean temperature over the mountainous areas of the upper Indus Basin, with seasonal differences. There was a rise in summer temperatures but a fall in winter temperatures and thus an increase in the seasonal temperature range. Taken together, the studies suggest that there has been an overall gradual increase in temperature in the Indus Basin, but with some differences in the reported seasonal trends.

Melt water, which is highly sensitive to temperature change, is particularly significant for flow in the Indus Basin. Glacier melt runoff provides an estimated 40% of total stream flow in the upstream areas and discharge generated by snow and glacier melt is 151% of the total discharge naturally generated in the downstream areas. The mean upstream water supply was projected to decrease by 8.4%, with the reduction in melt runoff partly compensated for by increased upstream rainfall. The decrease in glacier area led to a decrease in water supply from upstream areas [17].

However investigating the impact of climate change on the hydrological regime in a large spatial domain covering the Indus, Ganges and Brahmaputra Basins Lutz *et al*. [18] suggested that annual runoff will increase by 7–12% by 2050, primarily due to accelerated melt in the upper Indus Basin together with an increase in precipitation. Laghari *et al*. [19] also reported that water availability might increase in the short term, but will decrease in the long term. However, the projected future hydrology depends on the precipitation projections, which have a large uncertainty and large variation between annually averaged and seasonal projections.

China's Meteorological Administration reported that the temperatures in China rising four times faster than anywhere else. As a result, the Tibetan glaciers are retreating faster than other glaciers in the world. The short-term impact of this will be an increase in the formation of glacial lakes as well as the frequency of floods and mudflows and the long-term impact will be a decrease in river flow pattern [20].

Hydro-climatic damages are mounting in the recent past in India and Pakistan. With the Himalayan glaciers retreat, the most important short-term impact will be the Glacial Lake Outburst Floods (GLOFs). GLOFs are also related to climate change in that rapidly melting glaciers leave behind glacial lakes, which are then at risk of bursting due to destabilization of moraine dams. Historic records confirm incidences of GLOF events causing catastrophic flash floods [21]. The Indus basin has a total of 2,420 glacial lakes in the ten sub basins of Indus River, among these 52 glacial lakes are potentially dangerous [22].

Water Utilization in Indus Basin: India and Pakistan represent almost all of the demand on the river's resources, with Pakistan accounting for 63 per cent of total water used in the basin and India 36 per cent. Pakistan is critically dependent on the Indus: the country's other rivers are seasonal and their total flow is less than 2 per cent of the annual inflow that enters Pakistan through the Indus system. Agriculture dominates water use patterns in basins through Indus Basin Irrigation System (IBIS). Indus Basin Irrigation System (IBIS) of Pakistan was designed about a century ago with an objective to expand settlement opportunities, prevent crop failure and avoid famine. IBIS is a gravity run system with minimum management and operational requirements. The operation of IBIS is based on a continuous water supply and is not related to actual crop water requirements. Hence, it cannot accommodate changing water demands during the crop season. Irrigated lands supply more than 90 percent of the total agricultural production and are major user of the water resources [23].

The Green Revolution in the 1960s boosted agricultural growth in the Indian states of Punjab and Haryana and led to the Indus basin becoming the breadbasket of India. However, the repercussions of the Green Revolution and over-exploitation are now being felt with regard to the Indus waters (and particularly in relation to groundwater resources) in terms of both water quality and quantity [24].

The changing pattern of agriculture on both sides of border has brought drastic changes in the water scenario of the Indus basin. The diverse agricultural practices changed to mono-cropping pattern after the singing of Indus Water Treaty in the basin. In India, Punjab is utilising major share of Indus water system for agriculture. The gross cropped area in Indian Punjab under wheat increased from 40.5 percent in 1970-71 to 44.5 percent in 2010-11. Rice, which occupied around 6.87 per cent of the gross cropped area in 1970-71 in Indian Punjab, increased to over 33.15 per cent in 2007-08 and then rose further to around 35.85 per cent in 2010-11 (Table 4). The increase in

Table 4: Shift in Cropping Pattern in Indian Punjab, 1970-71 to 2010-11

	Percent to gross cropped area					Area (000'hectares)				
Crop	1970-71	1980-81	1990-91	2000-01	2010-11	1971-72	1981-82	1991-92	2001-02	2010-11
Rice	6.9	17.5	26.9	32.9	35.6	450	1269	2069	2487	2826
Wheat	40.5	41.6	43.6	42.9	44.5	2336	2914	3237	3420	3510
Maize	9.8	5.7	2.5	2.1	1.7	548	340	176	165	133
Cotton	6.9	9.6	9.3	5.9	6.1	475	686	719	606	483
Sugarcane	2.6	1.1	1.4	1.5	0.89	103	104	109	142	70
Pulses	7.3	5.0	1.9	0.7	0.2	384	325	90	49	20

Source: Statistical Abstract of Punjab, Various Issues.

Table 5: Number of tube wells, 1970-71 to 2010-11

Year	Number of tube wells (per 000'hectares)
1970-71	47.37
1980-81	143.06
1990-91	189.66
2000-01	252.47
2010-11	332.37

Source: Statistical Abstract of Punjab, Various Issues.

Table 6: Area under Crops in Pakistan Punjab, 1971-72 to 2010-11 (000'hectares)

Crops	1981-82	1991-92	2001-02	2008-09
Rice	1088.6	1231.4	1475.9	1977.7
Wheat	5167.2	5669.2	6101.8	6836.2
Maize	325.0	311.3	392.6	534.4
Cotton	1573.1	2286.9	2526.4	2223.7
Sugarcane	670.2	536.2	656.8	666.5
Barley	127.5	39.5	35.2	33.0
Jowar	209.0	212.1	241.2	182.7

Source: Crops Area and Production, 1981-82 to 2008-09, Vol I, Federal bureau of statistics, Government of Pakistan

wheat cultivation has been at the cost of gram, rapeseed and mustard, while that of rice has been obtained by shifting the area from maize, groundnut, millets and cotton. The proportionate area under cotton in 1970-71 was 7 per cent of gross cropped area and increased to 9.34 per cent in 1990-91. After mid 1990s the area under cotton has been adversely affected due to inclement weather and pest attack, its share in gross cropped area went down to 5.97 per cent in 2000-01. Respective share of pulses and oilseeds in gross cropped area has recorded a sharp decline from 7.29 and 5.20 per cent in 1970-71 to 0.25 and 0.71 per cent in 2010-11, respectively in Indian Punjab.

This happened due to assured profitability and minimum marketing risk of selected crops. Hence, area under water intensive crops had increased several times in the last four decades in Indian Punjab. The huge requirement of water for agriculture was met not only from surface water but groundwater has also been exploited on an alarming rate. The number of tube wells per thousand hectares in 1970-71 was 47.37 in Indian Punjab which increased to 332.37 in 2010-11 (Table 5).

The pattern of agricultural practices changed in almost similar way in Pakistan area of Indus basin as well. The Punjab province of Pakistan is utilising major share of Indus water system for agriculture. Area under rice cultivation had increased from 1008.6 thousand hectares in 1981-82 to 1977.7 thousand hectares in 2008-09 in Pakistan Punjab. Whereas, barley and jowar lost their area from 127.5 and 209.0 thousand hectares in 1981-81 to 33.0 and 182.7 thousand hectares in 2008-09 in Pakistan Punjab respectively (Table 6).

Total water withdrawal in the Indus river basin is estimated at 299 km^3. Irrigation withdrawal accounts for 93 percent of the total. The total area equipped for irrigation in the entire Indus river basin is estimated to be around 26.3 million ha, of which Pakistan accounts for approximately 19.08 million ha or 72.7 percent, India for 6.71 million ha or 25.6 percent, Afghanistan for 0.44 million ha or 1.7 percent and China for 0.03 million ha or 0.1 percent. The equipped area irrigated by surface water accounts for 53 percent while groundwater accounts for 47 percent [25].

The rural agricultural economy has been utilizing maximum share of Indus basin water. It does not mean that urban areas lack behind in utilization of Indus water. Water utilization is much higher among urban population as compared to rural in their daily needs in both the countries. Percentage of urban population is quite high in the Indus basin. More than one third population in Indian Punjab is urbanized where as in Pakistan Punjab half of the population is residing in urban areas. The proportion of urban population increased from 23.7 per cent in 1971 to 37.5 per cent in 2011 in Indian Punjab (Table 7). The growth of urban population in Pakistan Punjab was observed higher than Indian Punjab. In 1972, 24.4 percent of the total population was living in urban areas of Pakistan Punjab which increased to 31.3 per cent in 1998. The proportion of urban population in Pakistan Punjab was projected to be 42.5 per cent in 2015. The increasing proportion of urban population in Indus basin has raised the level of water utilization in the basin.

Table 7: Percentage of Urban Population

Year	Indian Punjab	Year	Pakistan Punjab
1971	23.7	1972	24.4
1981	27.7	1981	27.6
1991	29.6	1998	31.3
2001	33.9	2010	39.6*
2011	37.5	2015	42.5*

Source: Census of India,
http://www.pbs.gov.pk/sites/default/files/population_census/Administrative%20Units.pdf
* Jan B *et al*., [26].

Table 8: Large Dams on Indus River Basin (2010)

Country	Name	Nearest City	River	Year	Height (m)	Capacity (million m^3)	Main Use
India	Bhakra	Nangal	Sutlej	1963	226	9620	I, H
	Nangal	Nangal	Sutlej	1954	29	20	I, H
	Pandoh	Mandi	Beas	1977	76	41	I, H
	Pong	Mukerian	Beas	1974	133	8570	I, H
	Salal	Reasi	Chenab	1986	113	285	H
	Baglihar		Chenab	2008		33	H
Pakistan	Mangla	Mangla	Jhelum	1968	116	10150	I, H
	Tarbela	Ghazi	Indus	1976	137	11960	I, H
	Chashma	Mianwali	Indus	1971		870	I

Source: FAO,Aquastat
I denotes Irrigation, H denotes Hydropower

The soaring demand of water in the basin has been met by diverting and manipulating the Indus and its tributaries. Number of dams was constructed for maximum utilization of Indus water. Apart from utilizing for agriculture, industries and other uses Indus water was tapped for hydroelectricity generation.

The Indus basin has huge hydroelectric potential. The Pakistani part of the Indus river basin has a hydroelectric potential of about 50 000 MW. Its main gorge, between the Skardu and Tarbela, has a potential of almost 30 000 MW. Pakistan has used only about 10 percent of economically viable hydroelectric potential [27]. The hydropower potential of the basin in India has been assessed as 33832 MW. Upto March 2012 potential of 10779.30 MW has been developed and 4581 MW capacity is under construction. A major part of the potential, therefore, remains to be explored. The major important hydro power stations are Bhakra, Pong, Dehar, Ranjit Sagar, Chamera Stage - I,II,III, Nathpa Jhakri, Uri, Salal, Baghliar [28].

Water Quality of the Indus River Basin: Surface and ground water resources of Indus basin have been exploited to maximum extent to fulfil the growing needs of population in India and Pakistan. The rapid industrial and urban growth and use of pesticides and insecticides for enhancing agricultural production has been depleting the quality of water day by day in the entire Indus basin. Several studies found presence of heavy metals and harmful chemical concentration in the water of Indian Punjab - agriculturally most developed part of India. Quality of surface water is getting deteriorated due to waste disposal, municipal waste waters and surface runoff containing agro-chemicals from agricultural fields. Similarly, the concentrations of the heavy metal elements are found to be high in various shallow ground water samples collected from hand pumps of various parts of the Indian Punjab. In this agriculture rich region, agrochemical processes occurring in the calcareous soils in the region and use of agriculture additives are the major sources of hazardous chemical contamination of the ground water. The consequences of intensive water resource mobilization, in the absence of systematic ground water management backed by robust water governance mechanism, have lead to extreme depletion of groundwater resources on the one hand and a rising water level, leading to water logging and soil salinity, on the other hand [29-31].

Indus river basin area of Pakistan is also suffering from similar kind of water problems. Indiscriminate and unplanned disposal of effluents from agricultural fields, municipal and industrial wastewater into rivers, canals and drains is causing deterioration of water quality in the downstream parts. The groundwater is marginal to brackish in quality in 60 percent of the Indus Basin Irrigation System's (IBIS) aquifer. Use of pesticides and nitrogenous fertilizers is seriously affecting shallow groundwater and entry of effluents into rivers and canals is deteriorating the quality of freshwater. Almost all shallow freshwater is now polluted with agricultural pollutants and sewage [32].

Falling water tables and increasing salt contents in the pumped groundwater attest that, in future, groundwater will become more expensive and inferior in quality, which will have serious consequences for Pakistan's capacity to feed its growing population [33]. Pakistan has shortage of water in all areas, with higher vulnerability in the saline and more arid regions. Agricultural production in the lower Indus traditionally depended on the surface storage, but its depletion in recent years has forced the farming community to supplement irrigation requirement from the groundwater. Currently, groundwater contributes 35 per cent of the total water available to users in Pakistan. However, the current groundwater exploitation rates are unsustainable in several regions of, both, upper Indus basin and lower Indus basin. There is a large imbalance between extraction and replenishment [34].

Another effect of falling groundwater tables was the deterioration of groundwater quality. The quality of groundwater in the Indus Plains varies widely, both spatially and with depth and is related to the pattern of groundwater movement in the aquifer [35]. Areas subject to heavier rainfall and consequently greater recharge, in the upper parts of west Punjab, are underlain with waters of low mineralization. Similarly recharge occurring from the main rivers and canals has resulted in the development of wide and deep belts of relatively fresh groundwater along them. The salinity of the groundwater generally increases away from the rivers and also with depth. There are large numbers of saline groundwater pockets in the canal command areas of Pakistan Punjab and Sindh provinces. In Pakistan Punjab province, 23% of the area has poor groundwater quality, while it is 78% in Sindh province. In the lower parts of the Indus plain, the area of fresh groundwater is confined to a narrow strip along the Indus River. Similar situations can also be found in central areas of Pakistan Punjab province where a layer of fresh groundwater floats over the saline water. Due to excessive pumping of this thin fresh groundwater layer, the downward gradients are increasing thereby inducing salt water intrusion into fresh groundwater areas [36]. As a result of saline groundwater intrusion, about 200 public tube wells installed in the fresh groundwater zone of Pakistan Punjab and Sindh provinces had to be abandoned due to increase in groundwater salinity.

Water tables are falling at alarming rates, on both sides of the border in India and Pakistan. Excessive lowering of the groundwater table has made pumping more expensive. The present uncontrolled and unregulated use of groundwater is resulting in serious consequences. Problems of groundwater overexploitation will only become more acute, widespread, serious and visible in the years to come. If sound measures are not taken soon to ensure sustainable groundwater usage in the basin, the consequences for residents of the region may include a reduction of agricultural output and shortages of potable water, leading to extensive socio-economic stresses. However, the control of groundwater pumping is a difficult problem to be addressed, because it has become a major source of water supply for domestic and industrial uses, irrigation and food production in both the countries. The conjunctive use of surface and groundwater by farmers should be encouraged to minimize the problem of groundwater depletion in both the countries [37].

Indus Water Treaty: Mechanism of Water Sharing: The partition of the Indian subcontinent into India and Pakistan was also accompanied by the partition of its waterways. The partition of Punjab divided Indus river system, disrupting its well irrigated canals. Majority of the canals were served from their headworks, which remain in eastern side of the Radcliffe line.

After Independence, apart from other problems and conflicts, problems between the two countries arose over the distribution of water as well. Rivers flow into Pakistan territory from India. On April 1, 1948, India stopped the supply of water to Pakistan from every canal flowing from India to Pakistan. Pakistan protested and India finally agreed on an interim agreement on May 4, 1948.

In 1951, David Lilienthal, former chairman of the Tennessee Valley Authority (TVA), initiated the idea of Indus Water Treaty. Eugene Black, the World Bank President, was impressed by Lilienthal's ideas and in September 1951 wrote to the prime ministers of India and Pakistan, 'offering the Bank's good offices for discussions of the Indus water dispute and negotiation of a settlement'. The World Bank suggested a Working Group consisting of an engineer appointed by each country to jointly prepare a comprehensive long-range plan for the integrated management of the Indus Basin. A World Bank appointed engineer would serve as an impartial adviser during the initial phase, but he would not act as an arbiter. Black visited India and Pakistan and got the prime ministers of both countries to accept his proposals in

March 1952. It was agreed that water supplies to Pakistan for existing uses would be maintained during the discussion on long-term cooperation [38].

Finally, the Indus Water Treaty (1960) brought to an end, the 12 year old canal water dispute and became the basis of resolving any water related disputes which appeared after that. The treaty consists of three parts: the Preamble, Twelve Articles and Annexes A-H.

This treaty divided the use of rivers and canals between the two countries. Pakistan obtained exclusive rights for the three western rivers, namely Indus, Jehlum and Chenab. India retained rights to the three eastern rivers, namely Ravi, Beas and Sutluj [39]. Pakistan was allocated 81 percent of the Indus waters [40]. The treaty also guaranteed ten years of uninterrupted water supply to Pakistan. During this period Pakistan was to build huge dams, financed partly by long-term World Bank loans and compensation money from India. Three multipurpose dams, Warsak, Mangla and Tarbela were built. A system of eight link canals was also built and the remodeling of existing canals was carried out. Five barrages and a gated siphon were also constructed under this treaty.

While first four Articles focused on the use of water, Article V elucidates the provision of finances to be incurred on construction and remodelling of dams and canals. Under Article VI, specific provisions were made for regular exchange of river and canal data between the two countries and Article VII referred to future cooperation. Under Article VIII, both countries undertook to establish a permanent post of Commissioner of Indus Waters. Article IX highlights the settlement of differences and disputes. If the Commission is unable to resolve a specific problem, provisions have been made for reference to a Neutral Expert under Article IX and Annexure E. If the Neutral Expert fails to solve the problem, a Court of Arbitration can be convened under Article IX and Annexure G [41, 42].

Owing to the issues discussed above, in detail, the treaty currently is under tremendous stress. A number of issues are emerging with relation to water sharing between India and Pakistan. R. Iyer [43] explicated that when partition forced the two new countries to negotiate a treaty on the Indus waters, the negotiation was largely entrusted to engineers on both sides and the two opposing groups of engineers shared similar orientations, lexicons and concerns. The Indus Water Treaty was thus not merely a water-sharing treaty but also a water-control treaty. It is unfortunate that at the time of treaty water was considered as a matter for engineers alone. However, it is a complex, multi-dimensional substance that demands an inter-disciplinary study. Environmental concerns and climate change are post-Treaty developments and call for urgent inter-country consultations [44].

Major Water Sharing Issues Between India and Pakistan: Experts on transboundary water resources identify two key variables that define the likelihood and intensity of water conflict in a given river basin. The first is the amount and rate of physical or institutional change in the water system covered. The second is the strength of the cooperative institutions linking the riparians. Climate change will place unprecedented pressure on both and becomes very relevant when it comes to hydro politics in the Indus basin. Control over water resources, use of water as a political tool, its relationship with socio-economic development and threat of terrorists/non-state actors using it both as a target or a tool are quite relevant in the context of long-standing political rivalry between India and Pakistan [45].

The climate change and water insecurity in the basin have politicized the water issues further. For instance, in India, the per capita water availability is expected to decline below 1000 cubic metres by 2025 [46]. The growing water stress has coincided with India's plan to construct a number of hydropower plants, especially on the Chenab and Jhelum rivers. However Pakistan claims that India has not been forthcoming in sharing information and engineering details regarding these projects as required in the treaty. Pakistan also argues that the Indian projects have adverse trans- boundary impacts both environmentally and in terms of power generation as is evident in the case of Neelum-Jhelum project. Because water is a flowing resource rather than static entity, its use at any one place is affected by its use at some other place. It is a known fact that the use of water in one country can affect the timing of delivery for downstream users, even if the volume of water is unchanged [47].

Water issues have assumed such importance between India and Pakistan that they get top position in bilateral meetings between the two countries. As for Pakistan, the Kashmir issue is irrevocably linked to the Indus Water Treaty as the headwaters of all the rivers of Pakistan and meant for Pakistan, flow through Kashmir and India happens to be upper riparian state. The fear exists that India could manipulate water resources to starve Pakistan and hence water sharing issue is a core issue in India Pakistan relations [48].

Table 9: Chronology of major events in the Indus river basin

Year	Plans/projects/treaties/conflicts	Countries, agencies involved	Main aspects
1859	Completion of the Upper Bari Doab Canal	British Indian Colony	Canal irrigation development began to provide water for *kharif* (summer) crops and residual soil moisture for *rabi* (winter) crops
1872	Completion of the Sirhind Canal	British Indian Colony	From Rupar Headworks on Sutlej
1886	Completion of the Sidhnai Canal	British Indian Colony	From Sidhnai Barrage on Ravi
1982	Completion of the Lower Chenab Canal	British Indian Colony	From Khanki on Chenab
1901	Lower Jhelum Canal	British Indian Colony	From Rasul on Jhelum
1885-1914	Lower and Upper Swat, Kabul River and Paharpur Canals in NWFP (Pakistan)	British Indian Colony	Completed during 1885 to 1914
1907-1915	Triple Canal Project	British Indian Colony	Constructed during 1907-1915. The project linked the Jhelum, Chenab and Ravi rivers, allowing a transfer of surplus Jhelum and Chenab water to the Ravi.
1920	Indus Discharged Committee was established	British Indian Colony	Formed to record discharge data
1933	Sutlej Valley Project	British Indian Colony	Completed in 1933. Four barrages and two canals, resulting in the development of the unregulated flow resources of the Sutlej River and motivated planning for the Bhakra reservoir (now in India).
1930's	Sukkur Barrage and its system of seven canals	British Indian Colony	Completed. Considered to be the first modern hydraulic structure on the downstream Indus river.
1939	Completion of Haveli and Rangpur Canal	British Indian Colony	From Trimmu Headworks on Chenab
1947	Completion of the Thal Canal	British Indian Colony	From Kalabagh Headworks on Indus
1947	British Indian Colony divided into India and Pakistan		
1948	Water disputes between India and Pakistan	India and Pakistan	India unilaterally cut off supplies to Pakistan canals originating from the head-works located on the eastern rivers of Ravi and Sutlej
1954	Completion of the Nangal Dam	India	On the Sutlej River
1955	Completion of the Kotri Barrage	Pakistan	Was completed on the Indus River to provide controlled irrigation to areas previously served by inundation canals (as Taunsa and Guddu).
1958	Completion of the Taunsa Barrage	Pakistan	Completed to divert water to two large areas on the left and right banks of the river
1960	Indus Water Treaty (IWT)	World Bank, India, Pakistan	Resolved water disputes, Under the IWT all water of the eastern rivers shall be available for the unrestricted use of India. The three western rivers and all water while flowing in Pakistan of any tributary, which in its natural course joins the Sutlej main or the Ravi main after these rivers have crossed into Pakistan, shall be available for the unrestricted use of Pakistan (see "Water resources" section for details).
1962	Completion of the Guddu Barage	Pakistan	On Indus River
1963	Completion of the Bhakra dam	India	On the Sutlej River
1960-76	Indus Basin Project	Pakistan	Developed in pursuance of the IWT, including Mangla dam, five barrages (including Chasma reservoir), one siphon and eight inter-iver link canals, completed during 1960-1971 and Tarbela dam started partial operation in 1975-1976.
1974	Completion of the Pong Dam	India	On the Beas River
1977	Completion of the Pandoh Dam	India	On the Beas River
1986	Completion of the Salal Dam	India	On the Chenab River
2008	Completion of the Baglihar Dam	India, Pakistan, World Bank	ON the Chenab River. Disputes since the construction begun in 1999 between India and Pakistan. The World Bank finally authorized the construction.

Source: FAO, Aquastat.

Major Indian projects that have become matter of conflict between India and Pakistan from time to time and involved issues around the compliance of Indus Water Treaty include the Salal, Wullar Barrage/Tulbull Navigation project, Baglihar, Kishanganga, Dul Hasti, Bursar Dam, Uri II and Nimoo Bazgo and some others [49]. Pakistan's contention over some of these projects, like the Bursar Dam is not only linked to violation of the Indus water treaty but it has also underlined the environmental hazards associated with these projects.

A recent case in the fore was of Kishanganga dam. Pakistan had objected on the design of the dam and approached the International Court of Arbitration (ICA). The court has allowed India to move ahead with the construction on the condition that 9 cubic metre per second of natural flow of water must be maintained in Kishanganga river at all times to maintain the environment downstream.

Strategies for Water Cooperation: The Indus Waters Treaty set a precedent of cooperation between India and Pakistan that has survived three wars and other hostilities between the two nations. It is important, therefore, that the current disagreement over the violation of the treaty is resolved quickly so that it serves as a model for peaceful relations rather than an obstacle to cooperation. Whilst serving to construct a "new" world order of civil relationships, the Indus agreement continues to spin-off substantive economic, environmental and security benefits that promote sustainable development. In doing so, it has reduced regional suspicion and avoided inflaming regional insecurities [50]. Infact, no other water sharing treaty in modern world history matches the level of generosity on the part of the upper riparian state for the lower riparian one granted by India under Indus Water Treaty [51].

Recent Kishenganga final award by the international Court of Arbitration constituted under the Indus Water Treaty once again proved the strength and sanctity of the treaty. The treaty has withstood the test of time in showcasing on the global stage a fine example of peaceful and cooperative transboundary river water sharing. Although many water experts are demanding a renegotiation of the Indus Water Treaty which they contend is the need of the hour under changed circumstances. Exploring the prospective of Indus Water Treaty II under the prevailing political scenario seems to be a remote possibility. If India and Pakistan take a political decision to restructure their relations, they will have to ensure that water serves as a link to bring them together, rather than taking them further towards conflict.

Third party intervention can be sought for providing technical expertise, directing multilateral institutions and aid agencies to invest in projects to increase water efficiency in the region, involving its allies and private parties in efforts to promote economic cooperation and encouraging India and Pakistan to talk about a long-term outlook on water supply issues and move toward joint management of these challenges [52].

The waters of the Indus are being badly mismanaged on both sides of the border. The serious incidence of waterlogging and salinity and the intensity of internal water-related conflicts (interstate/inter-provincial) in both countries is evidence of mismanagement [53]. With better and saner water resource management, the situation in both countries may be very different and conflicts may diminish or disappear.

Water needs to be managed as a dynamic commodity. It is essential to set up an organization with representatives from India and Pakistan, which could function to identify short term and long term water capacity of the basin and its integrated development along with setting up of infrastructure and technical agencies.

Need of the hour is to address the increasing importance of improving irrigation system. As major share of water in Indus basin is utilized for agricultural sector hence, various forums and policy reports increasingly recognize the important role that water management plays in agricultural productivity. The irrigation application efficiency in Indus basin is 50 percent which is abysmally low [54]. Therefore, sound water management strategies are required to increase water productivity and minimize water losses. Proper utilization of water resources, both surface and underground, in Indus basin will help in reducing water stress in India and Pakistan.

Climate change and its implications on the hydrology of the Indus basin is also a crucial issue. On the one hand it will reduce the flow in the basin on the other hand aggravate hydrological disasters in the basin. India and Pakistan, the two largest riparians of the Indus should create a joint mechanism on climate change. This would involve conducting joint studies on the extent of glacial melt, creating joint mitigation and adaptation techniques, sharing information and improving flood forecasting systems. Debris dams, torrential surges and glacial lake outbursts are already causing severe damage to both India and Pakistan. This could be a specific area for cooperation. The effects of climate change on the Indus River basin make it imperative that the two countries discuss the water issue comprehensively.

India and Pakistan must adopt a transparent approach relating to sharing water and invite interdisciplinary communications. A holistic approach is required to understand the background and functioning of highly sophisticated irrigation systems. Besides, it is time that India and Pakistan along with other countries in the region come up with conservation policies, instead of creating more storage, that they have focused on for long. It is time for the strategy to harness our water resources to change from being a large scale capital and technology intensive and environmentally degrading option to management intensive and ecologically balanced development relying on indigenous technology.

Political considerations, of course, cannot be ignored while dealing with the water issue, especially keeping in mind the present environment of mistrust in India-Pakistan relations and their history of antagonism. Political leadership of the two countries should come forward with clear mind to resolve the issue.

Finally, India and Pakistan may focus on the following suggestions to harness the precious Indus water resource for the long lasting prosperity of the region;

- Improve cross-border dissemination of hydrological and meteorological data and data sharing on precipitation trends to develop better water policy.
- Implication of Geographical Information System (GIS) technology to analyse the proper status of water in the Indus Basin.
- Introduction of agricultural practices which consume less water and new techniques of irrigation to prevent water loss.
- Create awareness among the public of India and Pakistan regarding climatic change, its impact on environment, proper utilization of water, water harvesting, water recycling and water pollution.

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