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Water Conservation of Pakistan's Agricultural, Municipal and Industrial Water

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Abstract : Pakistan is located in semiarid to arid region where rainfall is highly deficient and does not match the crop requirements. Agriculture of country is mostly dependent on Indus River System (IRS). IRS maintains World's largest integrated irrigation network called Indus Basin Irrigation System (IBIS). Like other developing countries the population of cities and municipalities are increasing abnormally. The precious resource of water is scarce in this semi arid country. Pakistan is faced with the challenge of meeting the needs and aspirations of a very large population with very low natural and human resource base. The natural resources including energy and water are scarce in this semi arid country. The water situation is likely to be worsened by melting of glaciers as an outcome of global warming. Rapid development, management and protection of water resources have to be an integral element in a suite of policies to be developed to meet the environmental challenges faced by this country. This paper investigates and argues a case for changing mindset among policy makers and regional planners the water conservation, management and governance practices required in agriculture, municipal and Industrial sectors of the Pakistan can be adopted globally in the developing world based on last 2 decade data and based on the population growth and demographic trends forecast for the year 2025. The results show that water can be conserved by avoiding water pollution due to industries; by controlling population of the cities and municipalities finally the main consumer agriculture can be managed by good irrigation practices along with construction of dams to avert a possible threat due to climate change and population explosion in the country.

Key words: Pakistan • Indus River System • Indus Basin Irrigation System • Population growth and demographic trends • Global warming

INTRODUCTION

Water Conservation entails a complex interconnected system that includes a variety of aspects ranging from advanced technological equipment and practices to consumer education. Water conservation includes: programs and techniques designed to curb domestic, agriculture and industrial water use; wastewater reduction, treatment and reuse; and supply demand and replenishment- depletion relationship, energy consumption and environmental concerns. All aspects must be considered in relation to economic, social, religious, political, legal and aesthetic ties.

Water conservation concepts have changed drastically from fragmented supply oriented activities towards an approach which integrates supplier-user partnerships. Under Dublin Statement and Agenda 21, future water conservation strategies are to integrate water conservation as a basic component of integrated water resource management focusing upon public awareness and education to guarantee the involvement of public.

Pakistan has prepared a water conservation strategy which addresses all environmental aspects. Among these aspects, water conservation was placed at the top of priority. The strategy focused on community participation and involvement as a basic prerequisite for the success of any conservation policy in Pakistan. The strategy focused only on agriculture water and very little attention was given to domestic and industrial sectors.

Country Overview: Pakistan has an area of 796096 km^2 and a population of 160 million. According to population Pakistan is the 7th largest country in the world.

Pakistan's economy has undergone considerable diversification over the years yet the agriculture sector is still one of the largest contributor to the gross domestic product (GDP) having a share of about 22%.

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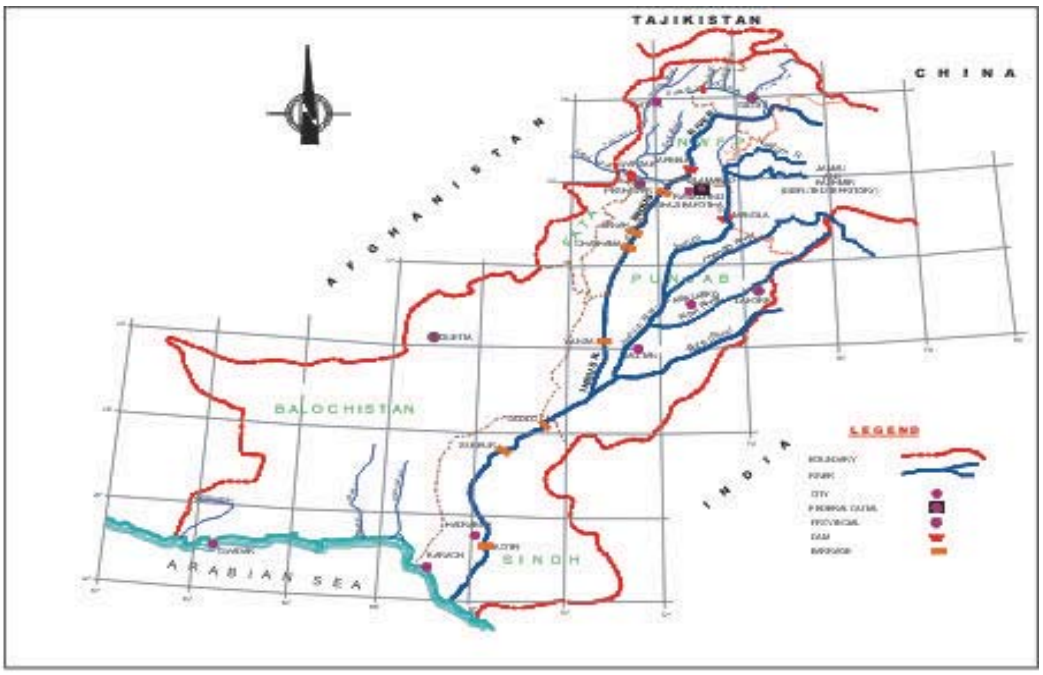

Fig. 1: Map of Pakistan showing River System of Pakistan

It accounts for 45% of total employed labour force and is the largest source of foreign exchange earnings and 90% water is used for this sector. During 2008-09 per capita income was US $ 800 (1US $ = Rs 85.10 at 2008-9 price level).

It is divided into four provinces, Punjab, Sindh, North West Frontier Province (NWFP) and Balochistan. Moreover some areas have special status these include Federally Administrated Tribal Area (FATA), Federally Administrated Northern Area (FANA) and disputed State of Azad Jammu and Kashmir with India (Fig. 1). Pakistan has Federal system of Government and provinces enjoy fair degree of autonomy.

- NWFP: 74521 km^2. having a population of 27.5 M (16% of the total)
- Punjab: 205, 344 km^2, having a population of 85 M (55% of the total).
- Sindh: 140,900 km^2 , having a population of 37 M (22% of the total)
- Baluchistan:347, 200 km^2, having a population of 10.5 M (7 % of total)

The Provinces of Punjab and Sindh account for 87% of Pakistan's urban population. Presently 70% of population has an access to clean drinking water and 55% has sanitation facility.

Indus River System (IRS): The agriculture of the country heavily depends on waters of Indus River System (IRS) that is fed by melting ice from glaciers in the Himalayas. IRS comprises of the rivers Indus, Jhelum, Chenab, Ravi, Bias and Sutlej and the northern and western tributaries (Fig. 1). Pakistan maintains the World's largest integrated irrigation network called Indus Basin Irrigation System (IBIS).

Indus River, with a length of about three thousand kilometers, is the longest in South Asia. It flows in the centre of Pakistan like a human spine. Indus River is fed from glaciers and summer monsoon rain waters.

Historical Background of Indus Basin Irrigation System (IBIS): Historically IBIS had 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 cut off the flows of the eastern rivers, on which most of the Pakistan's agriculture is dependent. The dispute was resolved through Indus Basin Treaty signed between Pakistan and India in September 1960 through mediation of World Bank.

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 man made canal system in the world) the IBP was designed and constructed to replace the waters of eastern rivers.

Under IBP works, two mega multipurpose projects (Mangla and Tarbela dams), five barrages one gated siphon and eight inter river link canals were constructed to regulate and convey water of western rivers to irrigation canals taking off from eastern rivers. WAPDA completed the construction of sixteen IBP components within a decade.

Availability of Water Resources: At the time of independence 5000 m^3 of water was available for each Pakistani, which has now reduced to 1000 m^3 because of uncontrolled population growth one of the highest in Asia.

Inadequacy in the availability of surface flows has led to excessive and uneven exploitation of groundwater. This unsymmetrical groundwater pumping has given birth to intrusion of saline water into fresh groundwater reservoirs due to vertical up-coning of saline interface or horizontal movement of saline aquifer.

Irrigated agriculture provides 90% of food and fiber requirement from about 17.2 million hectares (Mha) which is roughly 80% of the cultivated area while the remaining is contributed by 4 Mha of rain fed areas.

Major exploitable water resources of Pakistan are river flows, rainfall, glaciers and groundwater. Pakistan can be divided into three major river basins. However, the Indus river basin covers about 80% of surface irrigation system.

Average annual availability of flows of Indus river basin from Western rivers including diversions by NWFP and contributions of Eastern rivers and full scale Indian development and flow of other major basins are:

Western Rivers at Rim Stations	**BCM**
1976-77 to 2008-09	173.19
Average Annual Diversions Upstream by Nwfp	6.95
Eastern Rivers	8.80
• Sutlej below Ferozepur	3.72
• Ravi below Madhapur	1.40
• Ontribution within Pakistan	3.68
Total	188.94
Likely Future Uses	26.07
• Afghanistan	0.615
• Uses by India on Western Rivers	2.460
• Requirements below Kotri	6.150
• System Losses	16.851
Sub-Total	26.07
Balance Available	162.86
Existing Average Annual Canal Diversions (Upstream and Downstream Rims Stations)	130.49
Balance for Development	32.37

Monthly volumes of river flows, canal diversions and discharge below Kotri Barrage (last barrage on Indus River before it empties in Arabian sea) calculated on 10 daily basis for the post Tarbela (Dam on Indus River which supplements flow during low flow for Indus) period (1976-77 to 2007-08) shows that during the high flow periods, (July to September), large amount of water flows to the sea because of inadequate capacity of existing reservoirs. However, the average annual flows to the sea for the post Tarbela period is around 43 BCM.

Population Growth and Demographic Trends: Population growth is the single most important driving force affecting the water sector. Migration of population to urban areas has been a feature of demographic trends over the last 30 years and is expected to continue over the 2025 planning horizon. In 1972, a quarter of Pakistan's population lived in urban areas. The current proportion is about one third and projections suggest that, by 2025, more than half will live in towns and cities. Figure 1 shows the trends in total, urban and rural population growth since 1947 and the population projections to 2025. Pakistan's population in 2001 was 141 M presently 160 million, growing at a rate of 2.61 % between 1986 and 1998. With an assumed reduction in growth rate over the next 25 years, averaging at 2.1% the population is predicted to reach 221 million. With the rapid urbanization also taking place, the 2001 urban population of 48 M (34% of the total), increasing at 3.7% per annum, is predicted to be 114.5 M (52% of the total) by 2025.

Presently, almost a quarter of Pakistan's urban population lives in Karachi. The next five largest cities (Lahore, Faisalabad, Rawalpindi, Multan and Hyderabad) contain a further quarter of the urban population.

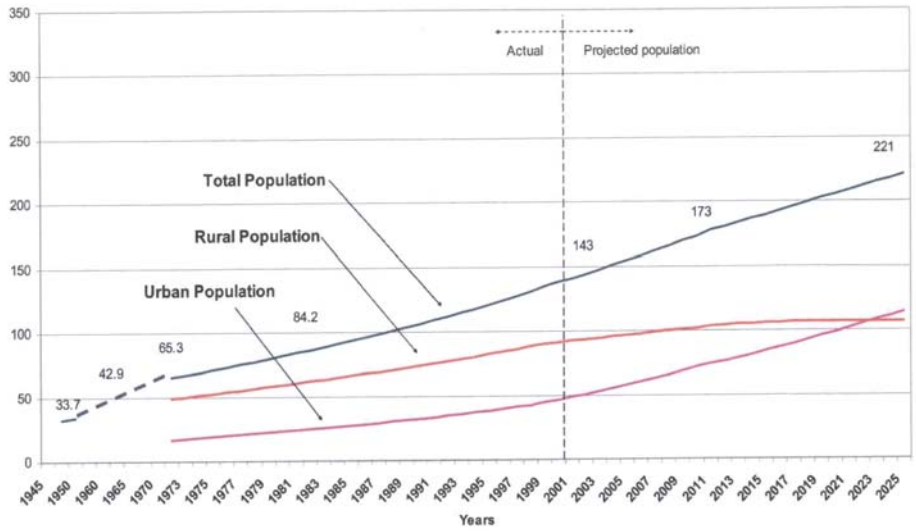

Fig. 1: Population (in millions) trends and projections

Table 1: Population projections in Pakistan

Sr. #	Year	Population (Million)
1	1951	33.74
2	1961	42.88
3	1972	65.31
4	1981	85.09
5	1998	130.50
6	2001	141
7	2008-09	160.40
8	Projected by 2025	220

Table 2: Pre and Post Dam Flows increase in system after construction of Terbela Dam

Province	Pre-Dams	Post Dam	% Increase[1]
Punjab	58.60	66.45	13.27
Sindh	43.70	54.70	25.06
NWFP	5.70	7.58	32.19
Balochistan	0.76	2.21	190.32
Pakistan	108.76	130.94	22.24

In Pakistan about 85 M people live in Punjab Province, which has an area of about 200,000 sq km. giving an average population density of about 450 persons per sq. km. within that province the four divisions of Lahore, Gujranwala, Faisalabad and Multan form the core of the province. These divisions cover only one-third of the land but contain two-thirds of the population. In other words the core of the province covers an area of about 70,000 sq. km. and houses about 60 M people. This translates into population density of over 850 people per sq. km.

Agriculture Water Conservation: It has been estimated that additional water requirements for Agriculture sector upto 2025 would be 45.50 BCM. Bulk 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). Flows in Rabi season are low because of the frozen glaciers and low rainfall during the winter season. It is reverse to the irrigation requirement, which is 60% for Rabi and 40% for Kharif.

More than 80% of Pakistan is located in arid or semiarid region of the world where rainfall is highly deficient and does not match the crop requirement. Irrigated area of Pakistan has increased from 8.4 Mha in 1947 to 17.2 Mha in 2010 (area under cereal crops increased by about 250%) and Cereals production increased from 5.2 million tons (Mt) to 27 Mt during the same period.

Thus, both horizontal expansion (increase in area) and vertical expansion (increase in yield) have contributed in the higher production of agriculture. For future scenario horizontal expansion would require additional land and water resources development while vertical expansion would entail better seeds, fertilizer, improved field management practices etc. Yield of cereal production Pakistan is about 1/3rd of the potential production with the same environmental setting. It has been anticipated that future needs of food and fiber would be met both by horizontal and vertical expansion, with about 50% contribution by each source.

[1]The increase in canal diversions is primarily during Rabi (October to March) season.

The river flow development to the tune of 45.50 BCM would be required under the optimistic scenario of 50% increase in agriculture through horizontal expansion by the year 2025.

In order to meet year round water requirement of crops, inter link canal systems and dams were construction in Pakistan from 1950 to 1974 with live storage capacity of 20.80 BCM. Construction of Tarbela and Mangla multi purpose dams/reservoirs and Chashma Barrage has provided flexibility in the transfer of seasonal flows from high flow period Kharif (April-September) to low period Rabi (October to March).

Annual canal diversion prior to construction of reservoirs was 108.76 BCM (Kharif of 74.16 BCM and Rabi 33.97 BCM) which has been supplemented by average annual storage releases by 18.60 BCM. The maximum diversion potential during Kharif (April-September) is about 86.1 BCM while for Rabi (October to March) is 49.9 BCM-.

Historic data evaluation shows that transfer capability was 12% without storages in 1960, which increased to 16% after the construction of Mangla in 1967 and Chashma in 1971. The flexibility further improved to 21% after commissioning of Tarbela Dam in 1976-77 due to joint operation of the three reservoirs. The transfer capability has decreased to 17-% in 2004 due to sedimentation of reservoirs which has reduced the live capacity of reservoirs by 6.25 BCM (32%) and 9.82 (43%) by the year 2025. The results indicate that Pakistan lost storage capacity equivalent to a mega dam till to date.

This indicates that dams have played a vital role in increasing provincial canal diversions. However, the capacity of dam is decreasing due to silt by about 185.2 million m^3/year.

Therefore high flow variation, historic diversion benefits during lowflow season from mega dam/reservoir projects and future fore casts for the year 2025 for 45 BCM of additional water dictates that mega storage dams be constructed to optimally use the water throughout the year according to crop requirements. Therefore, the storage dams are necessary to regulate water throughout the year one can say that water cannot be conserved without mega storage dams for irrigation and Agriculture of Pakistan.

Domestic Water Conservation: Currently domestic demand of water is 5.0 BCM which will be 13.00 BCM by the end of 2025 and urban population of the country will increased by about 40%. The situation is alarming with rapid urbanization, the provision of safe water supply and continuously depleting ground water due to excessive pumping in comparison to poor recharge. Moreover, the leakage problem contaminates water and directly or indirectly carries diseases like diarrhea, stomach infection etc. Ground water is vital resource, to fulfill urban water requirements. The estimated ground water in fresh water zone of Pakistan is 82 BCM. The main sources of recharge are rivers, tributaries, canal irrigation network and rain.

Due to over all population growth, water supply and sanitation infrastructure has already been in adequate to cope with the rapid urbanization. Moreover, none of the cities have complete provision to cater for total generated waste water. Untreated raw sewage in all cities is either used for irrigation or discharged in fresh water bodies creating serious environmental concerns and destroying water resources of the country.

Mostly the urban areas heavily depend on ground water for its water supply system. Due to excessive pumping in comparison to poor recharge the water aquifers are depleting day by day e.g. as a result the depth of fresh water table in Lahore having population more than 8 million where the author is based has fallen to about 200 m from 150 m with in last 2 decades.

Very high increase in urban population and densities put a lot of demand and stress on water resources presently and urban population forecast for the year 2025 is alarming for under ground water resource. Further water is short supply when requirements of such large numbers are considered but also the liquid and solid wastes generated (mostly discharged untreated) put huge stress on the natural environment.

Therefore to conserve quantity and quality of water upto mark in addition to the education of public migration of rural population to urban areas must be stopped. Moreover the main source of environmental/water degradation of pollution from domestic sources, arising from the extremely dense population. A number of health studies have indicated that a large proportion of deaths and illnesses stem from infectious diseases. The very high child mortality rate (more than 100) is attributed to diarrhea and other infectious ailments. Infectious diseases are closely related to pollution originating from human waste.

Industrial Water Conservation: It has been estimated that additional water requirements for industrial sector upto 2025 would be 2.50 BCM which can be catered quite easily. However, the basic conservation of water due to industries waste has been considered during this study.

For this study only Punjab the largest populated province of Pakistan is selected for conservation of water. Most industries in Punjab are of the agro-processing type. Industrial water for usage for future about 60% of the industries is engaged in textile manufacturing. Other major industries produce sugar, edible oil, leather, paper and soap. These industries are not a major source of air pollution and their effluents are mostly organic in nature (EUAD, 1993). With this information in mind and due to the limited resources available for this study, it was decided that only the biological oxygen demand (BOD) caused by industries would be estimated.

The results clearly indicate that industrial effluents play a minor role in the degradation (oxygen depletion) of the receiving water bodies. Industry seems to be responsible for very localized but probably severe environmental damage at a limited number of locations, which can be termed "hot spots". The extensive environmental degradation in the region stems primarily from the extremely dense and fast-growing population (bearing in mind that water pollution is the most critical environmental problem).

The estimates of industrial pollution are very liberal, due to the fact that industrial production capacities have been taken as industrial production figures (actual production may well be lower than the capacity). On the other hand, estimates of domestic pollution are very conservative, since contributions from the commercial sector have not been taken into account. Thus, the industrial contribution to the BOD load that actually reaches natural streams.

Moreover, the following facts offer further support to the findings:

- Contrary to the popular belief that Punjab is highly industrialized, industrial activity is very small in volume. According to the UNIDO (2008), there are a mere 550,000 manufacturing jobs in the whole country. Country's share in regional and world MVA (Manufacturing Value Added) was a mere 0.2%. The average value for even developing countries is four times that number.
- The environmental impact of industry depends on the industrial sectors. The industries that pollute the most are (in descending order) those that produce fabricated metal machinery, chemicals, petroleum, rubber and non-metals. Textile and food processing industries are considered to pollute less than all others (Hong, 1999). The vast majority of the industries in Punjab are of the least-polluting type.

Last but not the least everyone has to play one's role and don't waste water even while using water for ablution in running water as directed by our Prophet Muhammad (peace be upon him) and this Quranic verse of Surah Al A'raaf should be our preamble

Eat and Drink but Not Extravagance. Surely He Does Not Love Wastrels: Moreover, we should conserve water by not adding untreated sewage and industrial waste into fresh water streams as per Islamic norms of cleanliness.

CONCLUSIONS

- The main source of demand and stress on natural resources in general and water resources in particular is large population and very high densities existing in Pakistan. To cater for requirements of such large population it is inevitable to rapidly develop and manage water resources by building mega multipurpose storage dams and reservoirs.
- Not only population growth but rapid urbanization needs to be checked to avoid water scarcity and conservation. Aquifer recharging plans be prepared and implemented.
- Metered water system, needs to be adopted to control excessive use of fresh water.
- Chalk out Water Education Plans for awareness among people.
- The main cause of environmental degradation and water degradation is untreated waste from densely populated residential areas with a rapidly increasing population. Industrial pollution is local in nature. It can be very acute and damaging, but its spatial extent is limited. Pollution from industrial centers, or hot spots, affects only the people working in them and those living in the immediate vicinity.
- Installation of sewer water treatment plants, prior to discharging of domestic and industrial waste water into fresh water bodies for water conservation.

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