domestic purposes is a serious issue. Links between water quality & health risks are well established. According to UNCEF, 20-40 percent of hospital beds in Pakistan are occupied by patients suffering from water borne diseases.

In 1960s and 70s it was proclaimed that the "Green Revolution" would solve all the food problems. However, the new mode of cultivation, due to use of chemical fertilizers, herbicides, pesticides have destroyed bio-diversity, killed fish in the rivers, created salty soils and polluted rivers and source of drinking water. Over exploitation of groundwater and climate change phenomenon is another upcoming bound to complicate the situation further. Good quality water offers assurance against famine for food security and sustainability. Pakistan is a country with large arid & semi-arid regions where rainfall is sparse and insufficient for crop water requirements. Globally 40% of food production is produced from irrigated land. That is just 17% of cultivated land. But in Pakistan where annual rainfall is about 240 mm, 95% of food production comes from irrigated areas. Pakistan's canal irrigation system operates largely in a water-short environment. Although agricultural scientists have been doing remarkable job to cope with this situation, it is time to review the current situation, co-ordinate the individual efforts and develop a national workable strategy for sustainable water resource development & management.

TABLE-1
WHERE DOES PAKISTAN STAND IN
WATER AVAILABILITY vis-à-vis POPULATION

Year	Population (Millions)	Growth Rate	Total Water Availability		Per capita water availability (m^3)
			Billion cubic meter	MAF	
1951	34	0	178.8	144.9	5260
1961	43	2.38	178.8	144.9	4159
1971	63	3.89	178.8	144.9	2838
1981	84	2.72	178.8	144.9	2129
1991	111	2.83	178.8	144.9	1611
2001	143	2.60	178.7	144.9	1250
2010	172	2.10	178.6	144.7	1038
2020	204	1.70	178.9	145	877
2025	221	1.60	178.9	145	809
2030	238	1.50	178.7	144.8	751
2040	273	1.40	178.7	144.8	654
2050	311	1.30	178.8	144.9	575

Population Censuses Record					
Year	1951	1961	1972	1981	1998
Population	34	43	65	84	131

In future there are two kinds of challenges: One is the quantity of agricultural production and other is quality as well. The quality of agricultural product is a major concern for the WTO challenge. Thus it is very much required to develop crop production technology for sustainable production & increase the cropping intensity by bringing additional land under cultivation. Breeders should breed high yielding varieties. Similarly agricultural engineers will have to concentrate their efforts to modify and improve the existing irrigation techniques that are economical and well suited to our farming community and environment, especially to increase the overall water efficiency and salt balance issues upcoming through surface and groundwater application.

1.1 Present Situation

- Pakistan's current population of 168 million is expected to grow to about 221 million by the year 2025. This has a direct impact on the water sector for meeting the domestic water requirements of the people and for meeting the needs of agriculture to support increasing food requirements and produce an exportable surplus for earning foreign exchange. Over time per capita water availability and land use in Pakistan is shown in Fig. I and Fig. II respectively.

- Pakistan is now essentially at the limit of its water resources. There is some potential for additional storage but this is limited and, at present, the lack of consensus on storage between the provinces hampers its development. Additional water must be derived through conservation, especially in irrigation, where over 95% of water is used.

- While there has been continuous improvement in agricultural yields they remain significantly lower than their potential. Hence water for irrigation is not being utilized as effectively as it could with regard to crop production.

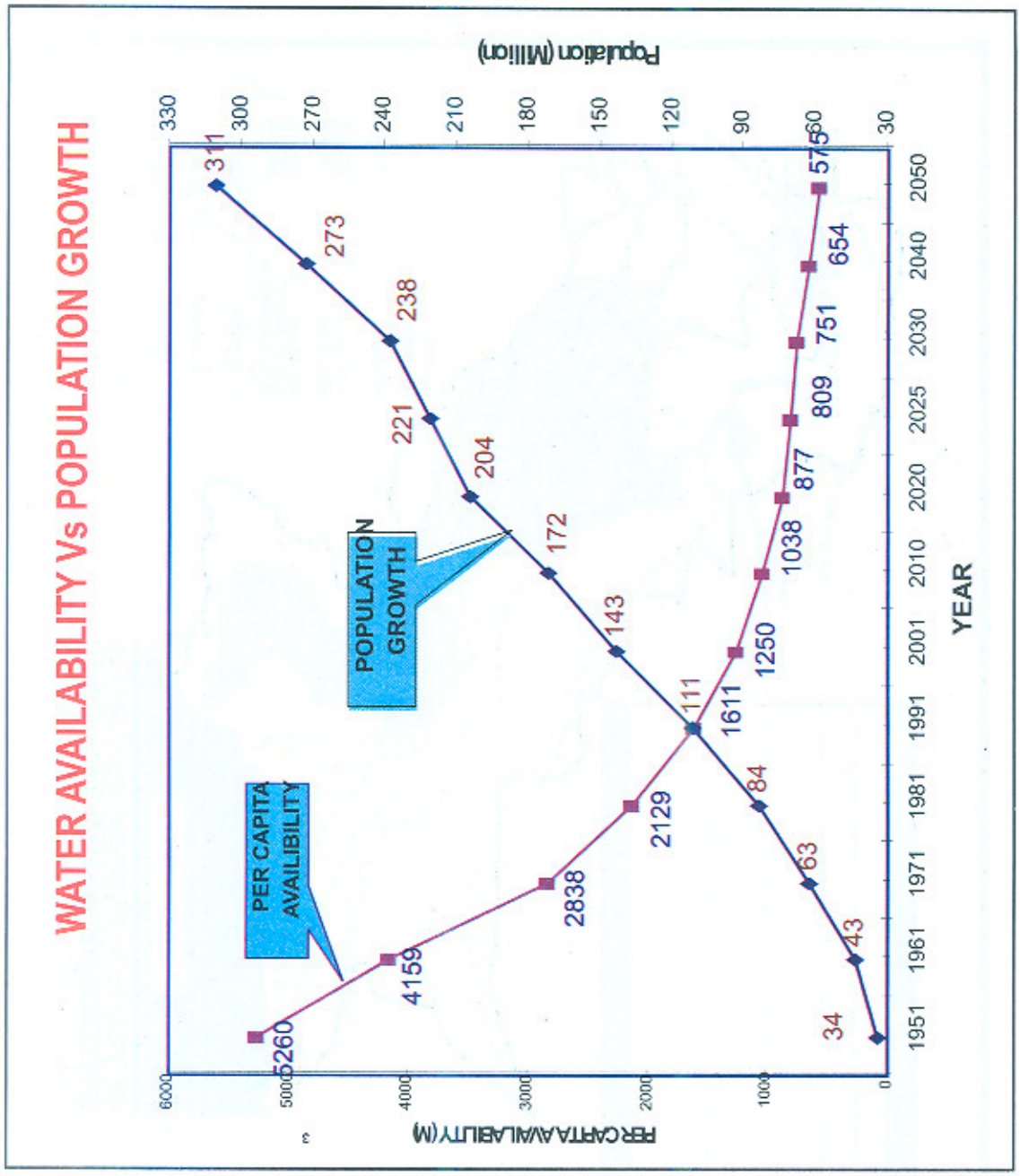
- Water quality in the rivers and other surface waters is low and deteriorating because of unchecked disposal of untreated municipal and industrial wastewater. Water quality monitoring and information management is lacking and yet is crucial to any water quality improvement programme.

- Information on water resources and, especially, water use is limited and not very accessible.

- Public awareness and understanding of water issues is lacking and needs to be addressed in order to garner public support for the changes in water management that will be needed in the immediate and longer term future.

- Access to clean domestic water in the urban and rural sub-sectors is low and significant investment will be required to improve service and keep up with the population growth.

- At a time when Pakistan is in dire need of investment in the water sector, there have been considerable delays in project implementation. There have


WATER AVAILABILITY Vs POPULATION GROWTH
PER CAPITA AVAILIBILITY
POPULATION GROWTH
PER CAPITA AVAILABILITY (M
Population (Million)
YEAR
6000
5000
4000
3000
2000
1000
0
330
300
270
240
210
180
150
120
90
60
30
1951
1961
1971
1981
1991
2001
2010
2020
2025
2030
2040
2050
5260
4159
2838
2129
1611
1250
1038
877
809
751
654
575
311
273
238
221
204
172
143
111
84
63
43
34

LAND USE IN PAKISTAN

CATEGORY	AREA (MA)
GEOGRAPHICAL AREA	196.7
AREA SUITABLE FOR AGRICULTURE	74.6
CULTIVATED AREA (IRRIGATED + BARANI)	54.5
AREA UNDER IRRIGATION (BY ALL SOURCES)	47.0
ADDITIONAL AREA THAT CAN BE BROUGHT UNDER IRRIGATED AGRICULTURE	20.1

SOURCE: AGRICULTURAL STATISTICS OF PAKISTAN 2007-08

been several causes for this, but most result in some way with lack of ownership on the part of the implementing agency.

2. Uses of Water

2.1 Water Availability

The average annual inflow of the Western Rivers during post Tarbela period 1975-2001) at the rim stations (Indus at Kalabagh, Jhelum at Mangla and Chenabat Marala) is 143.18 MAF (176.63 BCM). 82% of the total inflow is in the Kharif season (April – September) and 18% of the total-flows during the Rabi season (October – March).

The three eastern rivers, Ravi, Sutlej and Beas, have been allocated to India for its exclusive use, but un-utilized flows enter Pakistan. Allowing for the reduction in the contribution from the eastern rivers and the allowable uses by India on the western rivers the total long term surface water available in the Indus Basin is effectively equal to the inflow of the western rivers i.e. 143.18 MAF (176.63 BCM).

2.2 Irrigation

Irrigated agriculture is the major user of both the surface and groundwater resources of Pakistan. The average annual river diversions for irrigation in the Indus Basin are of the order of 103.84 MAF (128.10 BCM) for irrigating over 36 million acres (14.6 million hectares). Out of this 66.83 MAF (82.44 BCM) on average are diverted during the Kharif period, while 37.01 MAF (45.01 BCM) are diverted during the Rabi period.

During the Kharif seasons, on average basis of supplies Punjab used 34.3 MAF (42.3 BCM) annually on average, while Sindh & Balochistan used 31.4 MAF (38.7 BCM) and NWFP used 2.35 MAF (2.9 BCM). During the Rabi periods of the same period, average withdrawals by Punjab, Sindh & Balochistan and NWFP were 19.87 MAF (24.5 BCM), 16.06 MAF (19.8 BCM) and 1.46 MAF (1.8 BCM) respectively.

An estimated 41.6 MAF (51.3 BCM) are pumped annually from the groundwater reservoirs. Most of the groundwater abstraction is in the Punjab, estimated at 34.0 MAF (41.94 BCM) in 1999-2000, followed by Sindh at 5.0 MAF (6.17 BCM), Balochistan at 0.5 MAF (0.62 BCM) and NWFP AT 2.1 MAF (2.59 BCM). More than 90% of groundwater abstracted is used for irrigation.

The recent drought has caused considerable reduction in irrigation supplies. As a result there was a negative growth in agriculture. This has impacted on the growth of GDP.

It is interesting to note that there have been yield increase in some crops, notably wheat, despite, or in fact, because of the drought. The increases are in the areas of Punjab and Sindh which are normally waterlogged and have saline groundwater problems. The increases are attributed to a reduction in Waterlogging due to lower levels of water use as canal diversions have decreased. It remains to be seen whether the lesson here will be taken on board once the drought ends and water allocations are back to normal.

It is not possible to meet all future agricultural requirements with existing water resources alone, even with the development of additional storage. Much of the future requirements will have to be met through increased crop yields, increased water use efficiency, use of saline water for agriculture and recycling of effluents etc.

Table-2 WATER DEMAND

Population	**2010** **2025**	**168 million** **221 million**
Urban Population	Currently 2025	35% 60%
Total Area	196 M Acres	
Cultivable	73 MA	
Cultivated	52.5 MA	
Remaining	21.5 MA Needs Add. Water	
To increase the crop yield requires additional water		
Net Water Requirement	2010-11 2024-25	89 MAF 114 MAF
Domestic Demand	Currently 2025	4.0 MAF 10.5 MAF

2.3 Domestic and Industrial Water

The present water use for municipal supplies in the urban sector is of the order of 4.3 MAF (5.3 BCM). Most urban water is supplied from groundwater except for the cities of Karachi and Hyderabad and part of the supply to Islamabad. The increased population will exert additional pressure on the already strained water supply and sanitation facilities. The demand for municipal and industrial supplies in urban areas is expected to increase to about 7.1 MAF (8.7 BCM) by 2011 and 12.1 MAF (14.0 BCM) by 2025.

The total water requirement for non-irrigation use is estimated at 8.96 MAF (11.0 BCM) in 2011 and 15.3 MAF (18.9 BCM) in 2025. Irrigation water use will face increased competition from the municipal and industrial water supply sector.

2.4 Competition Between Uses

Irrigation dominates water use in Pakistan and is expected to continue as the major user of both surface and groundwater into the future. The existing reservoirs are operated with priority for the irrigation uses of the provinces as stipulated in the Water Accord. Hydropower generation is a secondary benefit from the reservoirs. Compared to irrigation the current demand for urban and rural water supply is minimal. However, as development proceeds and the population as well as country's economy grows, competition for water resources will become a major concern.

With the expected increase in the demand for supply of water for urban and rural domestic and industrial use, plus the needs of the environment, coupled with the limited overall water resources, it is likely that some water will need to be diverted from irrigation to these other uses. Currently, the irrigation system runs with overall efficiency of about 40%. There is some scope for conservation of water through increasing irrigation efficiencies to ensure water for all users, as well as ensuring adequate supply for irrigation itself. Urgent action is required for reducing losses from the irrigation system.

Disposal of effluents from agricultural drainage, municipal waste and industrial effluents into the canals, rivers and other water bodies are a major issue due to their effect on other water users. The disposal of untreated municipal and industrial effluent from all cities is already having significant negative impacts on downstream water quality.

Table-3
Competing Water Uses: Interaction

	Sanitary Control	Hydro-power	Irrigated agri-culture	Domestic water supply	Industrial water supply	Waste water disposal	Naviga-tion	Aqua-culture	Recreation / Fisheries
Salinity Control	2	C	C	1	1	2	0	2	2
Hydro-power			1	0	0	0	0	2	2
Irrigated agriculture				3	3	3	0	C	1
Domestic water supply					1	C	0	0	0
Industrial water supply						C	0	2	2
Waste water disposal							0	2	2
Navigation								0	0
Aqua-culture									C

O: no competition 1: minor competition 2: moderate competition 3: severe competition C: complementary use

3. Groundwater Quality

3.1 Irrigation Waters

The Indus Basin is formed by alluvial deposits carried by the Indus and its tributaries and is underlain by an unconfined aquifer covering about 15 million acres (6 million ha) in surface area. In the Punjab about 79% of the area and in Sindh about 28% of the area is underlain by fresh groundwater, which is mostly used as supplemental irrigation water and pumped through the tubewells. Some groundwater is saline and water from the saline tubewells is generally put into drains and, where this is not possible, it is discharged into the canals for use in irrigation after diluting with the fresh canal water.

About 42 MAF (52 BCM) of groundwater is pumped for irrigation use and for urban & rural drinking water supplies. Province-wise the groundwater usage is 34 MAF (42 BCM) in Punjab, 3.5 MAF (0.6 BCM) in Balochistan. Both the groundwater potential and use is very limited in AJ&K as compared to other provinces. In Northern Areas the potential for groundwater exploitation is virtually none.

Groundwater use is nearing the upper limit in most parts of Pakistan. The groundwater table in most of the fresh water areas is falling, therefore the potential of further groundwater exploitation is very limited. For future projections it is estimated that the additional contribution by groundwater may increase at best by 1-2 MAF (1.2 – 2.4 BCM).

The quality of groundwater ranges from fresh (salinity less) than 1000 mg /L TDS) near the major rivers to highly saline farther away, with salinity more than 3000 mg/L TDS. The general distribution of fresh and saline groundwater in the country is well known and mapped as it influences the options for irrigation & drinking water supplies. In the country some 14.2 million acres (5.75 Mha) are underlain with groundwater having salinity less than 1000 mg/L TDS, 4.54 million acres (1.84 Mha) with salinity from 1000-3000 mg/L TDS and 10.57 million acres (4.28 Mha) with salinity more than 3000 mg/L TDS.

Table-4 Water Quality Standards

Water Class	Electrical conductivity dS/m	Salt concentration mg/1	Type of water
None-saline	<0.7	<500	Drinking and irrigation water
Slightly saline	0.7-2	500-1500	Irrigation water
Moderately saline	2-10	1500-7000	Primary drainage water and groundwater
Highly saline	10-25	7000-15,000	Secondary drainage water and groundwater
Very highly saline	25-451	5,000-35,000	Very saline groundwater
Brine	>45	>45,000	Seawater

Punjab

About 79% of the area in Punjab province has access to fresh groundwater. Some 9.78 million acres (3.96 Mha) are underlain with groundwater of less than 1000 mg/l TDS, 3 million acres 1.22 Mha) with salinity ranging from 1000 to 3000 mg/l and 3.26 million acres (4.32 Mha) are underlain with groundwater of salinity of more than 3000 mg/l TDS. In the province, saline waters are mostly encountered in Central Doab areas. Cholistan area in the southern Punjab is well known for highly brackish waters, which can not be used for drinking as well as irrigation purposes.

3.1.2 Sindh

Around 28% of the area in Sindh province has access to fresh groundwater suitable for irrigation. Close to the edges of the irrigated lands, fresh groundwater can be found at 20 to 25 m depth. Large areas in province are underlain with groundwater of poor quality.

Indiscriminate pumping has resulted in contamination of the aquifer at many places where salinity of tube well water has increased. The areas with non-potable, highly brackish water include Thar, Nara and Tharparkar.

3.1.3. N.W.F.P.

In NWFP abstraction in access of recharge in certain area such as Kark, Kohat, Bannu and D.I. Khan has lowered the water table and resulted in the contamination from underlying saline water.

3.1.4 Balochistan

The Makran coastal zone and several other basins contain high brackish groundwater. As there is no alternative, local communities use groundwater for drinking purposes with TDS as high as 3000 mg/l.

It is apparent from the above discussion that as is the case with the quality of surface water, the quality of ground water in many areas is deteriorating due to contamination from industrial and municipal wastes and also due to salt water intrusion as a result of over pumping. Water quality of both surface and groundwater is becoming one of the major water resources issues.

For each of the % ages indicate whether stable, increasing or decreasing

Condition	Severe Impact	Moderate Impact	Slight Impact	No Impact
Area of aquifers where watertables are drawn by pumping	6.4% (Increasing)	3.6% (Increasing)	2.4% (Increasing)	87.6% (Decreasing)
Area of aquifers where chemical water quality is adversely affected by human activity.	12% increasing	9% increasing	9% increasing	70% decreasing
Area of aquifers where biological water quality is adversely affected by human activity	Negligible	Negligible	Negligible	99%

3.1.5 Estuarine & Coastal Zones

The coastal and estuarine zone of Pakistan is mainly affected by human activities in deltaic region except for small fishing villages scattered on the shoreline in Sindh & Balochistan. The kind of impacts generated by human activities include:

Estuarine

- Decrease in fish and other aquatic species.
- Depletion of mangrove system.
- Hyper-salination of creek system & depletion of habitat.
- Pollution through municipal sewerage and industrial effluent
- Sea water intrusion.

Coastal

- Loss of habitat
- Eutrophication
- Bio-accumulation of toxic substances
- Traffic & oil pollution in harbour areas.
- Smothering of inter-tidal flora & fauna
- Marine pollution due to port and harbour

The Indus estuarine area was once well known for its shellfish, Oyster, window pans oysters, shrimps and small pearls from species in the creek system. The catches of these landings have declined or completely ceased due to changes in hydrographic regions and environmental degradation. Traveling has also destroyed species in estuarine areas, which act as breeding and nursery grounds for several fish species. Traveling in the estuarine areas should be either banned or controlled and monitored.

3.1.6 Industrial Impacts

More than 60% of the industries of the country are located in five industrial complexes near the coast in Sindh and Balochistan. Sindh Industrial Trading Estate (SITE), Hub Industrial Trading Estate (HITE), Landi Industrial Trading Estate (LITE), Korangi Industrial Trading Estate (KITE) and the Port Qasim/Steel Mill Complex , Karachi, with an estimated population of 13-14 million generates more than 262 MGD (499.3 MCP) of untreated domestic and industrial waste water. The disposal of periodic Oxygen deficient water in the proximity of coastal region has resulted in many important fish species moving farther away from the fishing zones.

Quantitative estimates of oil pollution on the Karachi creeks are lacking. However, observations indicate considerable amounts of oil and tar balls from shipping traffic washed up on the coast. This is probably due inadequate flushing water. The influence of pollution from Karachi Harbour and Gizri-Korangi creek system is noticeable to a radius of 10-20 Km' offshore. Flotsam and oily wastes are visible to a radius of 5 Km. Bottom sediments show sings of organic pollution to a distance of 15 – 20 Km offshore from Korangi – Phitti creek opening

3.2 Domestic Waters

Poor microbial quality of drinking water supplies is by far the dominant water quality issue for health in Pakistan. In most of the cities the municipal water is unsafe to drink and does not meet WHO guidelines. In cities the quality of the water is generally compromised with the distribution system by inadequacy or lack of chlorination, cross-connections from sewage lines, poor maintenance and illegal connections. Many surface water treatment plants do not observe basic procedures to ensure water quality. It is estimated that 90% of the country's population is exposed to unsafe drinking water. There is an increasing trend in cities and urban areas on the use of costly bottled drinking water. Several bottling companies have started operating but a recent survey, reported in the Press, showed that the quality of water supplied by a number of these companies also did not meet WHO standards for drinking water.

For water in rural area across Pakistan, there is simply no system in place to assess the quality of drinking water. The availability of drinking water in rural areas where groundwater is saline is a serious problem.

For each of the % ages indicate whether stable, increasing or decreasing

Condition	Severe Impact	Moderate Impact	Slight Impact	No Impact
%age (by length) of coastal line whose aquatic eco systems are affected by human activity	11.5%	15.3%	8.8%	64.4%
%age (by area) of estuaries in which the salt water interface has advanced in land as a result of human activity	90%	10%	0 %	0 %
%age (by area) of estuaries whose aquatic eco systems are adversely affected by human activity	90%	10%	0 %	0 %

3.2.1 Sindh

In Karachi the tap water is not fit for drinking. Almost 95% of shallow groundwater supplies are faecally contaminated and surveys suggest that similar pollution occurs elsewhere in the province of Sindh. The presence of chlorinated pesticides in shallow groundwater sources in Karachi has also been reported. Many rural areas of the province (in particular Mirpur Khas and Thar) are also faced with high fluoride content in the drinking water.

3.2.2 NWFP

The quality of drinking water in NWFP is often low due to the aging distribution system, the lack of treatment facilities and contaminated water sources in some urban areas. Drinking water in Peshawar is generally unfit for human consumption due to faecal contamination. In certain saline areas in Nowshera, Kohat and D.I.Khan, water is unfit for drinking due to a high salt content. Nitrate concentrations as high as 946 mg/l have been reported from rural areas around Gadoon.

3.2.3 Punjab

The drinking water quality in major urban centres of the Punjab seldom meets WHO Guidelines. Samples obtained from Lahore, Rawalpindi and Islamabad is reported to be unfit for human consumption due to faecal contamination. High concentrations of nitrates have also been detected in drinking waters in Islamabad, Rawalpindi, Gujar Khan, Kahuta, Murree and Taxila. Nitrate leaching from heavy fertilizer use is known to be an issue in southern Punjab. Many areas near Lahore have very high fluoride content in drinking water supplies, which resulted in ailments in the consumers.

3.2.4 Balochistan

In Balochistan, the main environmental health problems arise from higher levels of faecal coliform, viruses and pathogens in water supplies obtained even from deep wells. The problem is specially acute in Quetta. Some of shallow aquifers are contaminated by sewerage & other pollutants. An additional problem is that of hyperfluorosis. Drinking water in Jafarabad, Dera Bugti, Mastung & Bolan areas have been found to contain high fluoride content.

4. Areas to be addressed urgently at Public & Private Levels

4.1. Water Storage

To meet future water requirements, it would be necessary to create large storages on Indus River. The Federal Government through WAPDA has launched a comprehensive integrated water resource and hydropower development Mega Plan Vision 2025 for development of water reservoirs and hydropower generations. Under this programme water storage/reservoir sites of about 65 MAF total capacity and power potential sites of 35,000 MW in the whole of Pakistan including Northern Areas & AJ&K have been identified. The Vision Programme envisaged a comprehensive portfolio for undertaking feasibility studies, detailed engineering designs and preparation of tender documents of a number of projects. Under Vision 2025 Programme, implementation of such projects as Raised Mangla Dam, Gomal Zam Dam, Hingol Dam and Mirani Dam etc. has been undertaken on fast track basis. Basha Diamer, Akhori, Munda dams have been taken up already or would be taken up in future.

4.2. Environment

Through out the country river and stream behaviour is changing due to increased diversions, construction of reservoirs and deforestation of catchments. Silt loads, particularly in the wet season, create a problem in all sub-sectors using surface water. Suspended matter in the water creates a greater rate of component wear on pumps and turbines and increases filtration problems in any situation requiring clean water. Sedimentation of reservoirs is resulting in reduction of capacity and other irrigation infrastructure poses an ongoing maintenance problem in an environment where attention to maintenance is not given a high priority.

Environmental use of water has not received recognition in the past. For future development of storage reservoirs allocations may be made for the environmental use so that the downstream adverse effects are mitigated. Significant further investment is required in public awareness and education, farmer training and institutional strengthening.

Pakistan is likely to face acute problems in near future, as its water resources will not be adequate to supply water to cities, towns and rural areas, or to produce enough food crops to meet the requirements of an increasing population. The most environmental concern is the low quality of surface water, which should be addressed through improved wastewater treatment in both the urban water and industrial sub-sectors.

Water quality monitoring and information management is badly lacking in Pakistan. Developing a monitoring system, which would include the establishment of water quality laboratories, and training of personnel for those labs, should be given emphasis in a water sector strategy.

Watershed management, especially the loss of forests in the upper catchments which, among other things, contributes to the sedimentation of reservoirs is a concern. However, at present there is little information on the impact of forest loss. Initial research on this would be warranted. There are several environmental issues which, if unchecked, will make the water use unsustainable. These include:

- Widespread contamination of surface waters due to disposal of agricultural drainage and untreated municipal and industrial effluents causing high incidence of water-related disease;
- waterlogging and salinity;
- over exploitation of groundwater in certain areas;
- limited forest cover and deforestation;
- saline intrusion into aquifers due to over pumping and
- reduction in the capacity of major reservoir due to siltation.

4.3 Federal and Provincial Institutions

At the Federal level Ministries of Water & Power, Food, Agriculture & Livestock, Planning & Development, Environment, Local Government and Rural Development and Ministry of Finance & Economic Affairs deal with water, agriculture and energy related issues. The Principal Institution involved in the planning, design, implementation of irrigation, drainage and power projects at the federal level is the Water & Power Development Authority (WAPDA).

At the Provincial Level Departments of Irrigation & Power, Planning & Development, Food and Agriculture, Physical Planning & Housing Department (Punjab) and Public Health Engineering Departments (Other Provinces) and Finance Departments deal with water and agriculture related issues. The Provincial Irrigation Departments/Provincial Irrigation & Drainage Authorities (PIDAs) are responsible for the planning, design, implementation & operation of irrigation & drainage systems and the flood control infra-structure in their respective provinces. While there is no general concern with the organizational structure of water institutions in Pakistan, there is no body at the federal level which has the responsibility to oversee the water sector as a whole and which has no vested interest in construction or other forms of water sector development.

4.4 Crops Substitution

The types of crops grown need to be rationalized to ensure that the crops grown are efficient in terms of water use and economic productivity. The traditional cropping pattern of rice and wheat has benefited from increased irrigation supplies and these two crops will remain important in Pakistan. However, sugarcane production, for example, has resulted in poor economic allocation of resources and wasteful over production that

could not be efficiently marketed, resulting in a break down of support price mechanism and major loss to the producers. Over investment in the sugar industry and increased allocation of land and water to sugarcane has resulted in reducing resource availability to other crops. Modern research has shown several alternative cropping patterns that can raise productivity of existing farm systems. In the intensive agriculture systems of Punjab, Sindh and NWFP, there are ample opportunities to increase farm income from technologies such as zero tillage, introduction of high value crops like sunflower, pulses, vegetables and orchards etc.

4.5 Introduction of Sprinkler and Drip Irrigation

There is potential for reducing water use through introducing sprinkler and drip irrigation for some crops in some areas. Capital investment can be intensive for modern mechanized irrigation. Consideration should be given to introduction and means of financing these modern irrigation system in the scenario of present increasing scarcity of water in Pakistan.

4.6 Recycling of Effluents after Treatment

There is potential to re-use waste water effluent after treatment. However, care must be taken to ensure that the effluent is treated before use for irrigating food crops. Treatment of waste water effluent needs to be given priority from the environmental and water quality concerns.

4.7 Use of Saline Water for Agriculture

The use of saline water for cropping is restricted to growing salt resistant crops. Such crops as grasses for fodder, bushes and trees have proved successful in providing a reasonable economic return from areas affected by saline soils or using saline water for irrigation. This may not have a wide spread benefit, there is likely a potential for local improvements in farmer income.

4.8 Flood Water / Hill Torrents Conservation

One mode of rain harvesting which is used in Pakistan in watersheds of hill torrents and small streams is through construction of check dams to retard the speed of flows and construction of delay action dams to flatten the flood peaks and use the run off either for recharging the groundwater aquifer or to divert it into channels for use in flood irrigation. This technique has become popular in the water scarce areas of Balochistan, NWFP and parts of Punjab. In urban and rural areas rain harvesting can also be introduced in public and community wells situated near slums, draining water from nearby roof-tops and streets into them.

4.9 Conservation and Productivity

Country's productivity is one of the lowest in the world. The future strategy should be to look into enhancing productivity of existing irrigated land with high efficiency irrigation and adopt knowledge based technologies. Similarly in other water related sub sectors, conservation technologies can reduce or at least meet their water requirements more efficiently.

4.9.1 Desalination

Water quality for domestic use is a major problem across Pakistan. There are significant costs associated with the treatment of the raw water. For coastal cities such as Karachi, and inland cities, which have access to brackish groundwater, there is potential to benefit from desalinating water which should be investigated as a possible future source.

5. Conclusions

- Pakistan is presently faced with the situation that all its developed water resources are inadequate to meet the irrigation, power and other water requirements and it will not be able to meet its growing water requirements by 2025.
- Future water needs can be met by using available water resources more efficiently but in many cases it will be necessary to make increased use of low quality water for agricultural production.
- The irrational use of low quality groundwater has resulted into mining & secondary salinization.

5.1 Recommendations

- Impacts of low quality water for agriculture must be assessed at the farm level as well at the regional level.
- Traditional surface irrigation methods should be altered/replaced by properly designed and managed micro sprinkler & trickle irrigation systems.
- Disposal of industrial & sewerage effluents should be brought under strict legal frame work.

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SUSTAINING IRRIGATED AGRICULTURE IN THE 21ST CENTURY : OPTIONS FOR PAKISTAN

By

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ABSTRACT

Pakistan is also one of those countries that could face severe food shortages in the 21st century, which are intimately linked to water scarcity. It is projected that shortfall of water requirements would be about 32 percent which will result in 70 million tones of food shortages by the year 2025. It is also predicted that after an initial period of high flows in the form of storms due to faster glacial melt there will be a terrifying decrease in inflows of anywhere between 30-40 percent into the Indus river system. Recent estimates suggest that climate change and siltation of main reservoirs will reduce the surface water storage capacity by 30% by 2025. This reduction in surface supplies and consequent decreases in groundwater abstraction will have serious effect on irrigated agriculture, which produces more than 90 percent of the total agricultural production in Pakistan. This situation has threatened the food security of 170 million people living in Pakistan. It is, therefore, imperative that Pakistan should invest soon in increasing storage capacity, improving water use efficiency, managing surface water and groundwater resources in a sustainable way to avoid problems of soil salinization and water-logging. Current low productivity in comparison to what has been achieved in other countries under nearly similar conditions points to the enormous potential that exists. Of course, building capacity of individuals and organizations and strengthening institutions are key elements for achieving these targets.

BACKGROUND

Indus Basin Irrigation System (IBIS)

The Indus Basin Irrigation System (IBIS) commands a gross irrigable area of 16.85 million hectares (Mha), of which 14 Mha is culturable command area (CCA) to which water is allocated. The perennial canal supply is available to 8.6 Mha while the remaining area is entitled to irrigation supplies only during the summer (Kharif) season. The Indus River and its tributaries, on an average, bring 175 billion cubic meters (BCM) of water annually. This includes 165 BCM from the three Western Rivers (Indus, Chenab and Jehlum) and 10 BCM from Eastern Rivers (Ravi, Beas and Sutlej). Most of this, about 128 BCM, is diverted for irrigation, 35 BCM flows to the sea and about 12 BCM is wasted as the system losses (Zuberi, 1997).

The average safe groundwater yield is estimated to be about 63 BCM, whereas the extraction for agriculture, domestic and industrial sectors is of the order of about 52 BCM. Thus the remaining groundwater potential is about 11 BCM (PWP, 2001). While these figures may suggest some potential for further exploitation of groundwater, other evidences such as increasing salinity in the groundwater due to redistribution of salts in

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the aquifer and declining groundwater levels confirm that potential for further groundwater exploitation is very limited.

Increasing Gap in Supply and Demand

The water requirements for irrigation in the Indus Basin are estimated at 250 BCM in 2025 against the availability of 185 BCM. Even by exploiting the full groundwater resources, the water availability will not be more than 190 BCM. Considering the reduction in present storage capacities due to siltation and non-availability of additional storage facilities, the shortfall of water requirements would be about 32 percent by the year 2025 (ADB, 2002). In the "business as usual" scenario, shortfall of water will result in serious food shortages in the years to come and will severely hurt the national economy and livelihood of millions. Estimated requirements of the agricultural commodities for the project population in 2025 are given in Table 1.

Table 1: Projected food requirements and productions for the year 2025 (Million Tons).

Crops	Requirement	Production	Shortfall
Food-Grains	50	31.5	18.5
Sugarcane	82	46.4	35.4
Cotton (lint)	3.5	2.7	0.8
Pulses	1.9	1.4	0.5
Oilseed	3.3	1.5	1.8
Vegetables	14.3	9.0	5.3
Fruits	16.1	9.0	7.1
Total	171	102.8	69.4

Source: ADB water Sector strategy for Pakistan, 2002.

Low System Efficiency and Crop Productivity

Pakistan has a large stock of water infrastructure with an estimated replacement cost of about US$ 60 billion (World Bank, 2006). Much of this infrastructure is very old and operating beyond their designed life. The services provided by this infrastructure are very crucial for sustainable irrigated agriculture and the national well being. However, these services can only be available if the structures are well maintained and, when their useful life is over, replaced.

The overall irrigation efficiency in the Indus basin is about 30% (Bhutta and Smedema, 2007). In addition to water shortage, lack of inputs and poor irrigation practices, soil salinization are the other major factors for low crop yields. The average yields in Pakistan are low for wheat and rice, being 2276 kg ha^{-1} and 1756 kg ha^{-1}, respectively. There is a great variability in crop yields with some farmers achieving yields of 3874 kg ha^{-1} for wheat and 3545 kg ha^{-1} for rice (Qureshi, 2004).

Inequity in Water Distribution

Conceptually the major task for water managers in the Indus Basin is to provide water in a predictable and timely manner to those who need it and have a right to it. This task is done less and less satisfactorily due to monoply, discretion and corruption in the water sector. The water bureaucracy has yet to make the vital mental transition from that of builder to that of manager. The "*warabandi*" distribution system favors head-enders and

discriminate tail-enders, which has serious implications for equity and crop productivity. Within watercourses, tail-enders get 20% less water than middle-enders, who in turn get 20% less water than head-enders. Similar trends are seen in the productivity levels of head, middle and tail-enders of the same watercourse.

Degrading Water Infrastructure

Pakistan benefited immensely from the major water infrastructure built in the Indus Basin. The benefits from Tarbela dam substantially exceeded those which were predicted at the time of construction (World Bank, 2007). Through forward and backward linkages in the economy, the total benefits were probably about twice those of the direct power and irrigation benefits. However, with age and neglect, much of the water infrastructure is in poor shape resulting in huge system losses and low performance in carrying water to the tail reaches of the canal commands. Many elements of the vast hydraulic system are now reaching the end of their design lives, and have to be rebuilt/rehabilitated. There is an enormous backlog of deferred repair and maintenance. Most of the recent irrigation and water supply "investments" have been for the rehabilitation of poorly maintained systems and not for the construction of new infrastructure.

Degradation of the Resource Base-soil Salinization

There is abundant evidence of wide-scale degradation of the natural resource base. The Indus Basin is faced with a considerable salt balance problem. The salts are brought in by rivers and their tributaries. On an average, about one ton of salts is added to each hectare of irrigated land. This accumulation is the main cause of land salinization. Salt-affected soils have become an important ecological problem in the Indus Basin—an estimated 4.5 million ha are already afflicted, about half of which are located in irrigated areas (Qureshi et al., 2004). Of course, the scale of the problem of salt accumulation in the root zone would be even greater if saline groundwater is used for irrigation.

Figure 1 shows that problems of salinity are more serious in the Sindh where about 54% area is saline. The main reason for higher salinity in the lower parts is low rainfall, high evapo-transpiration rates with shallow and saline groundwater. Groundwater is used for irrigation both in isolation and in conjunction with the canal water. The conjunctive use of surface water and groundwater is now practiced on more than 70% of the irrigated lands of Pakistan resulting in soil salinity problems.

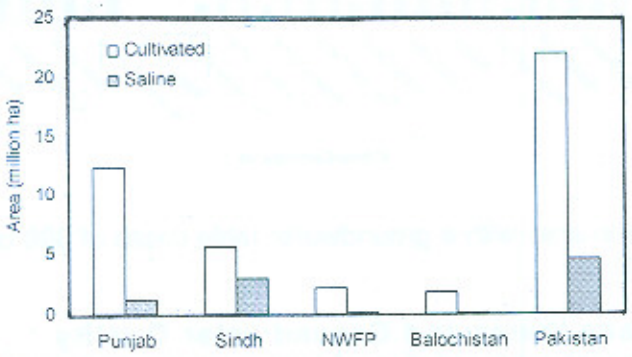


Figure 1: Province-wise distribution of cultivated area and salt-affected area (WAPDA, 2007).

Over-exploitation of Groundwater

Over the past three decades, farmers have largely taken the problem of surface water scarcity into their own hands, and "solved it" by sinking hundreds of thousands of tubewells to feed their thirsty crops. The number of private tubewells have increased from 10,000 in 1960 to about 0.6 million in 2002 (Qureshi et al., 2003) and about 0.8 million in 2006 (World Bank, 2007). The total groundwater abstraction from these tubewells is estimated at 51 x 10^9 m^3 against a recharge of 40-60 x 10^9 m^3. The management challenge is to stabilize the groundwater table at levels where the cost of pumping is affordable. Over-exploitation of groundwater has already caused severe water table decline in most canal command areas of Punjab and Sindh provinces (Figure 2). The average decline in groundwater table is about 1.5 meters per year. The excessive use of groundwater in cities has also led to falling water levels and contamination.

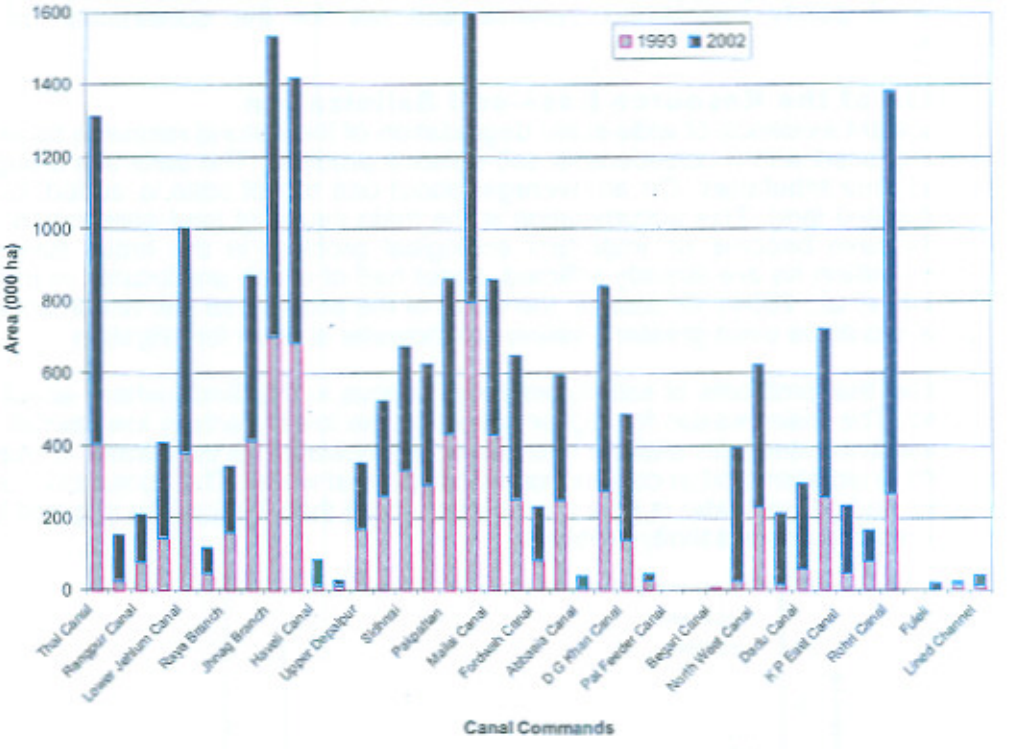


Figure 2: Increase in area with a groundwater table depth of 300 cm between 1993 and 2002.

Deteriorating Surface Water and Groundwater Quality

There is large-scale uncontrolled pollution of surface water and groundwater from the increasing quantities of pesticides and fertilizers used in agriculture and by rapidly growing cities and industries. Major cities have inadequate sewage treatment plants. Many are either non-functional or working poorly. And there is only one industrial

common effluent treatment plant working in the whole of the country. The result is the presence of heavily degraded surface water around all cities and towns.

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 (Qureshi et al., 2007). The salinity of the groundwater generally increases away from the rivers and also with depth. In Punjab 23 percent of the area has hazardous groundwater quality, while it is 78 percent in Sindh (Haider, 2000).

An Inadequate Knowledge Base

The Indus Basin is a single, massive, highly complex interconnected ecosystem, upon which man has left a huge footprint. In a system so massive and complex, the generation and smart use of knowledge are the keys to adaptive management. But there has been very little investment in Pakistan in building this knowledge base and the accompanying institutional and human systems. This is going to be a major constraint in the future when we seriously embark on implementing our strategy. In the past Pakistan has relied heavily on outside knowledge, especially in sciences. Now Pakistan needs to develop its indigenous capacity and make a major push to establish and nurture a new set of institutions that will provide the scientific, technical and policy support for the management of increasingly scarce water.

Non-development of Areas Outside the Indus Basin

The food insecurity-poverty nexus is also pervasive in Pakistan. Poverty in Pakistan, as is the case with most developing countries, is linked to overall growth performance of the agricultural economy. In Pakistan, poverty in irrigated areas is usually attracted by non-irrigated areas. In earlier days of irrigation people migrated from water poor areas to the basin to settle and develop lands. Limited water availability now no longer allows for such migration. The alternate is to develop water resources in those areas outside the basin and offer more livelihood opportunities in their own environment. It is worth mentioning that about 20% of the total water resources of Pakistan are located outside the Indus basin. Therefore it is important to invest in spate irrigation structures in these areas to improve water access for agriculture.

The Way Forward-Key Areas to Focus

The problems of water resources management in Pakistan are complex and a straightforward solution seems impossible. In order to increase agricultural production and ensure sustainability of irrigated agriculture, the overall strategy should be to increase water capital and make better use of water. For quick response to water and food security needs, issues of increased water and land productivity, water delivery efficiency and environmental and ecological sustainability, the following options can be considered:

Increasing storage capacity and modernizing irrigation infrastructure

Relative to other arid countries, Pakistan has very little water storage capacity that is hardly 15% of the annual river flow. The per capita water storage capacity in Pakistan is only 150 cubic meters as compared to over 5,000 cubic meters in USA and Australia and 2,200 in China (Figure 3). The dams of the Colorado and Murray Darling rivers can

store 900 days of the river runoff, South Africa can hold 500 days in the Orange River and India between 120-220 days in the Peninsular Rivers. In contrast, Pakistan can hardly store 30 days of water in the Indus Basin (World Bank, 2006). If no new storage is built in near future, canal diversions will remain the same and the shortfall will increase by 12 percent in the next decade. The Pakistan Water Sector Strategy estimates that Pakistan needs to raise its storage capacity by 22 BCM by 2025 in order to meet the projected requirements of 165 BCM.

In the past few years, government is emphasizing more and more on the construction of small dams to provide irrigation facilities to the small scale irrigation schemes. The small

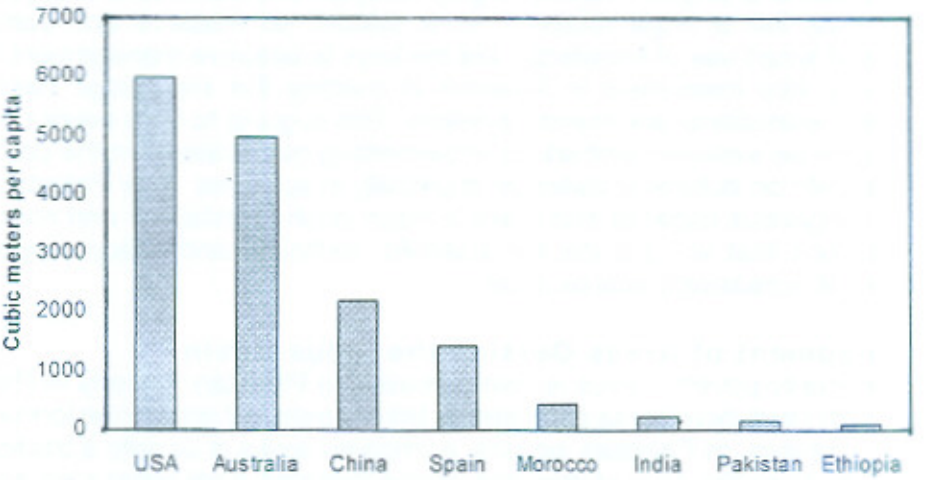


Figure 3: Storage per capita in different semi-arid countries.

dams may address to some extent the poverty issues in selected villages but would not help in eradicating poverty in large areas. The envisaged small dams will have a storage capacity of about 1850 cubic meters, which is good to meet the requirements of small scale irrigation and meet domestic water requirements. But in no way can they be considered as true replacement for large dams. For instance, to store water equivalent to Kalabagh dam we would need to construct 750 small dams, and that too will be exclusive of power generation. Therefore, where it is necessary to build small dams, the importance of large dams should not be ignored as they are imperative for sustained national economic growth.

Another area which is linked with the agricultural development and needs immediate attention is the construction of farm to market roads so that farmers can bring their produces directly to the competitive markets. Pakistan's post harvest storage and processing industry is also very weak and need to be strengthened. More than 20% of the agricultural products are wasted due to non-availability of proper storage and post harvest processing facilities. Construction of grain storages close to larger markets will greatly help in providing farmers security in the post harvest period. With these storages there will also come about financing arrangements for sustaining and increasing their