# Prospectives and Limits of Groundwater Use in Pakistan

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## Abstract

*Groundwater use in Pakistan has increased due to increased demand for expanding agricultural, industrial and domestic water use. Due to increasing population and lack of surface water storage, development pressure on groundwater has increased. Annual groundwater abstraction has increased from 10 billion cubic meter (BCM) in the year 1965, to 68 BCM in the year 2002. Unplanned groundwater abstraction has caused excessive lowering of water table in certain areas, mobilization of deeper saline groundwater, secondary salinization and higher pumping costs. More than 80 percent groundwater exploitation is being done by farmers in private sector. About 17 percent area of Punjab and 75 percent area of Sindh province are underlain by saline groundwater. About 70 percent of tube wells in these areas are pumping saline water for irrigation use.*

*Countrywide soil surface and profile salinity surveys were conducted in 1953-54, 1977-79 and 2001-03. Comparison of data of surface salinity has indicated that salt free land has increased from 56 percent to 73 percent of the approx. 17.0 M ha surveyed. The area affected by surface salinity has decreased from 42 percent to 21 percent. Data of profile salinity within 1.5-meter depth indicated that salt-free profiles have increased from 55 percent to 61 percent and saline profiles decreased from 44 percent to 39 percent. Similarly, severely waterlogged area also decreased in general. This trend is more pronounced in Punjab due to better water management whereas the opposite is true in case of Sindh due to poor water management. There are more than 600,000 irrigation tube wells causing depletion of groundwater (GOP, 2003). Pollution due to agricultural, industrial and human activities, water logging, secondary salinization due to poor drainage, and poor groundwater governance are the main groundwater problems. Use of pesticides has increased from 665 tons in 1980 to 45,680 tons in 1999. Increased use of fertilizers and pesticides has caused groundwater pollution. To overcome these problems, it is recommended to: (i) Develop a groundwater regulatory framework; (ii) Expedite transfer of SCARP tube wells from the public to the private sector; (iii) Strengthen monitoring efforts to determine sustainable groundwater potential and use; (iv) Promote groundwater recharge wherever technically and economically feasible; (v) Delineate areas with falling groundwater table in order to restrict uncontrolled*

*abstraction; (vi) Improve water management practices; (vii) Capacity building of groundwater centers/ institutes; (viii) Launch awareness/extension campaign for better water management, and (ix) Prepare a database to delineate: (a) groundwater development potential; (b) water quality zones; (c) water table depth zones; and (d) types of tube wells to be installed.*

## Introduction

Before the introduction of canal irrigation system, the depth to groundwater in Pakistan was generally 20 to 30 meter below the natural surface level. The sources of recharge were rivers, floods and rainfall. The technology for extraction of groundwater was Persian wheels driven by animals. Hence, the use of groundwater for irrigation was limited. It was practiced mainly near the rivers or in low-lying areas. For centuries, the elevation of the groundwater remained more or less at the same level with only seasonal fluctuations.

After introduction of canal irrigation, in the beginning of the 20$^{th}$ century, the groundwater table started rising till it reached close to ground surface in 1960's. At present, mean annual canal diversions are 128 BCM. A major part of it seeps down from rivers, canals, watercourses and fields and recharges the groundwater. This is an additional and continuous source of recharge to groundwater causing water logging and secondary salinization due to salt accumulation in the top-soil when water from shallow depth evaporates.

## Importance of Groundwater

Groundwater is a reliable resource, which can be utilized any time. Groundwater is used for agriculture, drinking water supply and industry all over the world, including Pakistan. Thirty five percent of agricultural water requirements in Pakistan are met from groundwater. Most of the drinking water supplies are also drawn from groundwater.

If cost of one tube well is taken as Rs. 50,000, the total investment for groundwater development in Pakistan will be Rs. 30 billion. Groundwater development is a significant factor in alleviating poverty, especially in rural areas where groundwater access secures the agricultural output. Groundwater usage contributes US$ 1.3 billion to the national economy per year. Studies have shown that due to use of groundwater, yields of crops have increased 150-200 percent and cropping intensities have increased from 70 to 150 percent (Qureshi, 2004).

## Groundwater Potential

A simplified Indus Basin water balance is given in Table 1. It is estimated that total annual groundwater recharge is equal to, or less than, discharge which means no further significant groundwater development can be done. In this estimate it is assumed that recharge and discharge from rivers are equal. If evapotranspiration from the groundwater is taken into account the water balance becomes negative.

## Groundwater Development

The number of existing private tube wells in Pakistan is over 600,000. The rate of increase is 20,000 tube wells per year. The discharge of the private well-functioning tube wells is 0.8 cusec (23 l/sec).

Groundwater table is falling in almost all the canal commands since 1998. It indicates that current net groundwater abstraction[1] is higher than recharge. Thus the groundwater development at the current pace is unsustainable.

Table 1. Groundwater recharge of the Indus Basin

| Location | | At head | Infiltration | | Recharge to aquifer | |
|---|---|---|---|---|---|---|
| | | (BCM) | % | (BCM) | % | (BCM) |
| 1. | Canals Diversions | | | | | |
| | Canals | 128 | 15 | 19 | 75 | 14 |
| | Distributary / Minor | 109 | 8 | 9 | 75 | 7 |
| | Watercourse | 100 | 30 | 30 | 60 | 18 |
| | Fields | 70 | 30 | 21 | 90 | 19 |
| | Crops | 49 | | | | |
| | Sub-Total | | | 79 | | 58 |
| 2. | Rainfall: Average rainfall of 0.195 m over area of 17.4 M ha. | | | | | |
| | Rainfall recharge | 34 | 50 | 17 | 50 | 8 |

## Challenges of Groundwater Management

Groundwater management is facing the following challenges:

- Depletion due to overdraft;
- Pollution due to agricultural, industrial and human activities (highly polluted cities);
- Water logging and secondary salinization due to poor water management and drainage and unregulated conjunctive use; and
- Poor groundwater governance.

## Groundwater Depletion

There is no mechanism for regulating groundwater use in Pakistan. Groundwater rights are not protected under legislation. Anybody having land and sufficient financial resources can install a tube well on his or her land and abstract any amount of water at any given time without consideration of safe yields. Groundwater abstraction from 1965 to 2002 has increased from 10 BCM to 68 BCM. Over 80 percent of groundwater is exploited by the private tube well owners/farmers.

Unplanned pumpage is creating severe management and equity problems. Due to continuous lowering of water table, groundwater is becoming inaccessible

[1]Here, net groundwater abstraction means the groundwater abstracted and not returned to the groundwater, i.e. the water being depleted by evapotranspiration.

to small farmers, which is threatening the sustainability of irrigated agriculture. Already 5 percent of the tube wells in Punjab and 15 percent in Balochistan are beyond the reach of poor farmers. This situation is likely to increase to 15 and 20 percent in the two provinces, respectively (Mohtadullah, 2004).

## Deterioration of Groundwater Quality Due to Salinization and Pollution

Groundwater salinity in various provinces is shown in Figure 1. About 17 percent area of Punjab and 75 percent in Sindh is underlain by saline groundwater (TDS>3000 ppm). About 70 percent of tube wells pump saline water for irrigation, which is escalating secondary salinization. Problems are not only due to salinity but also sodicity.

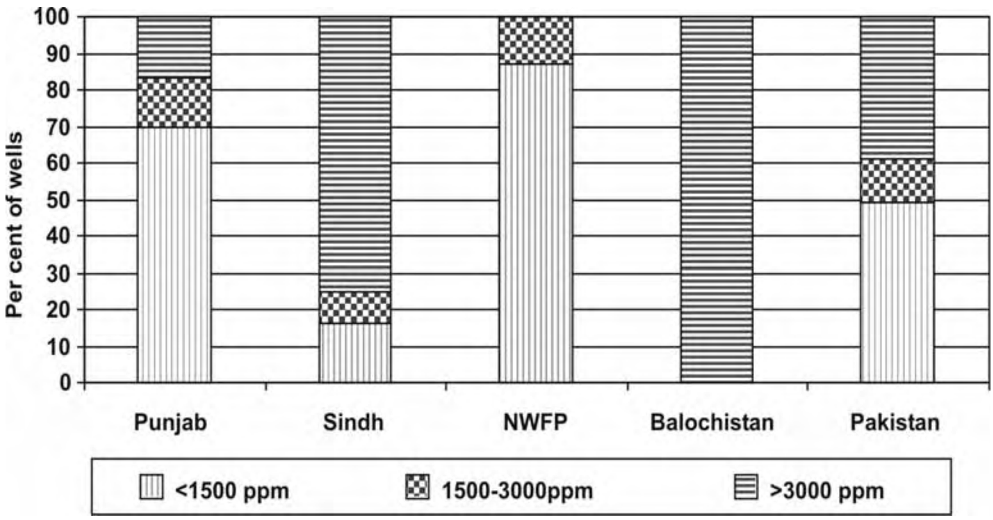


Figure 1. Groundwater quality (TDS, total dissolved solids) in various provinces, measured in existing wells, at depths of 20 to 50m

Leaching from municipal and industrial effluents, fertilizers, pesticides, solid wastes, and disposal of saline drainage effluent and seawater intrusion causes pollution and contamination of groundwater.

Untreated sewage and sullage in urban areas are disposed off into rivers and other surface water bodies through a mixed system of open drains and sewage pipes in the major metropolitan centers and primarily through open drains in the other urban centers. It is estimated that in the province of Punjab, 112 cumecs of municipal and sewerage effluent is being disposed off into the river bodies. The major part, i.e. 83 cumecs, of municipal and sewerage effluent of Lahore city is disposed off into the river Ravi. Leakage of effluents from septic tanks and sewerage drains endanger the aquatic and human life.

A large number of industrial units are scattered throughout Pakistan in rural and urban areas. These units dispose their wastewater into the nearby drainage channels and ponds causing contamination of groundwater and polluting surface water. Some industrial effluents are highly toxic and are discharged without any treatment. It has been estimated that only about 1 percent of the wastewater produced annually in Pakistan is treated before disposal into water bodies (ADB, 2002).

It is estimated that in the province of Punjab, 14 cumecs industrial effluent is being disposed into water bodies. In the Sindh Province, 7 cumecs industrial/ municipal effluent of the Hyderabad region is being disposed into water bodies.

Use of fertilizers and pesticides is increasing day by day for the hunt of higher crop yields to meet the pressing needs of a growing population. For the improvement of crop yields and quality, the government has encouraged the use of insecticides, especially in the production of cotton. As a result, the use of pesticides increased from 665 tons in 1980 to 45,680 tons in 1999 (ADB, 2002). However, excessive application of pesticides has caused the prevailing insect species to develop resistance and has resulted in pollution of surface water and groundwater.

## Water Logging and Soil Salinity

### *Extent of Water Logging*

Groundwater table in the Indus Basin canal commands exhibits an annual cycle of rise and fall. It is at its lowest point in the period prior to the monsoon (April/June). Recharged through *Kharif* season (summer) irrigation and rains, it rises to its highest point in October, when it is closest to the land surface before declining again. High watertable conditions after the monsoon, although transitory, interfere with the cultivation of *Rabi* season (winter) crops. The water table position in April/June is, particularly critical and is used as an index of water logging. On average (1993-2002), about 12 percent of the canal command area is severely waterlogged (disaster area), with water table depth less than 150 cm (0-5 ft.).

Overall trend of disaster area for the period from 1978-2003 is depicted in Figures 2 and 3. The disaster area was maximum in 1999 due to heavy rains and abnormal floods in 1998 and minimum in 2000 due to drought conditions in Pakistan.

On an average, the percentage of disaster area slightly decreased from 13.0 percent during 1979-82 to 12.9 percent during 1983-92 and to 11.2 percent during 1993-2003. Data given in Figure 2 and 3 show that the disaster area decreased in Punjab province (due to growth of private tube wells), remained constant in NWFP and increased in Sindh/Balochistan (due to poor water management).

### *Extent of Soil Salinity/Sodicity*

The first countrywide soil salinity survey was conducted in 1953-54 under the Colombo Plan assistance, covering an area of 16.8 M ha. In terms of surface salinity, an area of 9.4 M ha (56 percent of the area surveyed) was salt free, 3.3 M ha (20 percent) was slightly saline, an area of 1.5 M ha (9 percent) was moderately saline and an area of 2.2 M ha (13 percent) was strongly saline whereas, miscellaneous land types included 0.35 M ha (2 percent of the area surveyed). Overall, about 42

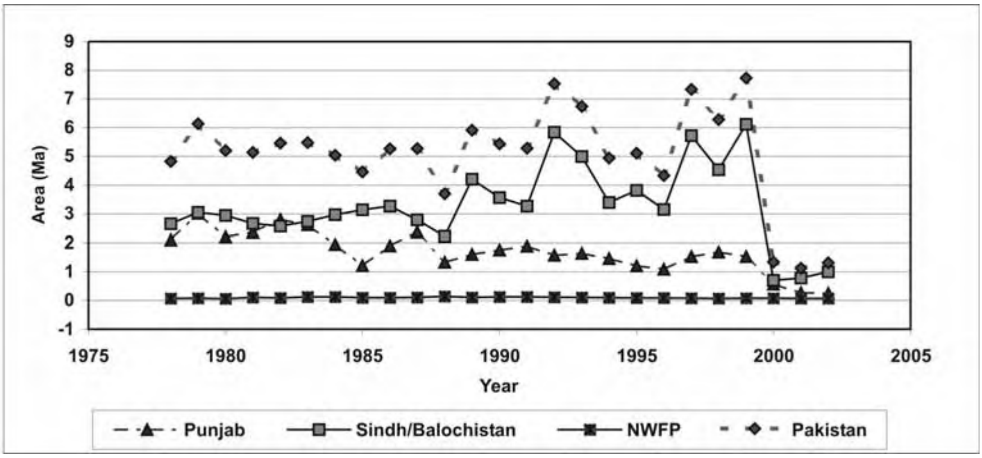


Figure 2. Severely waterlogged (Disaster) area (Groundwater level within 150 cm of the soil surface)

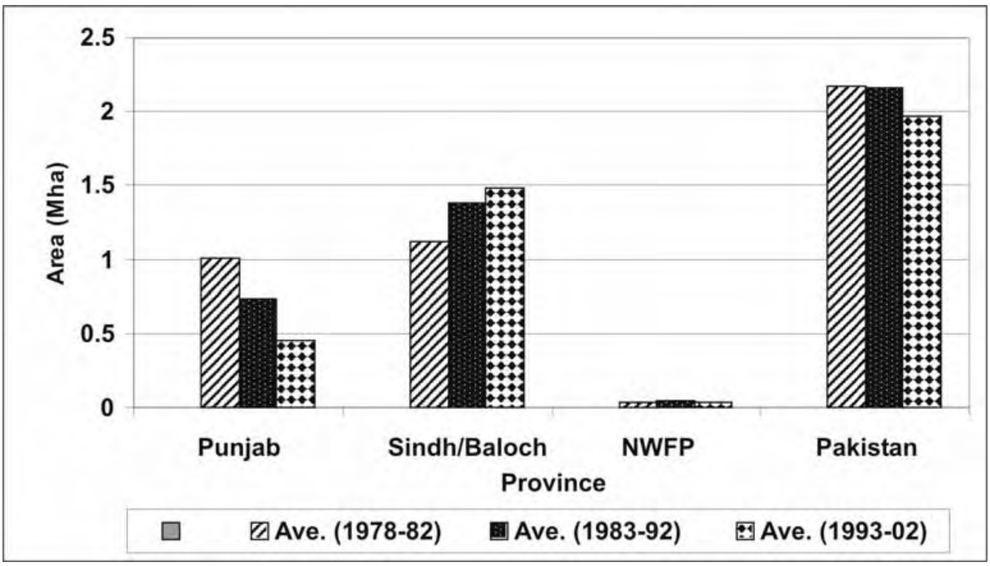


Figure 3. Average severely waterlogged (Disaster) area

percent of the area was affected by surface salinity. Surface salinity of different surveys is depicted in Figure 4 and profile salinity in Figure 5.

The second survey was conducted by WAPDA during 1977-79. In this survey, covering 16.7 M ha, both surface and profile salinity was established through chemical analysis of the soil. In terms of surface salinity, an area of 12.1 M ha (72 percent of area surveyed) was salt-free, 1.9 M ha (11 percent) was slightly saline, an area of 1.0 M ha (6 percent) was moderately saline and 1.3 M ha (8 percent) was strongly saline, whereas miscellaneous land types included 0.43 M ha (3 percent). About 25 percent of the area was affected by surface salinity.

The latest salinity/sodicity survey (2001-2003) has recently been completed by the Soils and Reclamation Directorate (S&R), WAPDA. Under this survey 16.8 M ha area was surveyed. In terms of surface salinity, an area of 12.3 M ha (73 percent of the area surveyed) was salt-free, 1.8 M ha (10 percent) was slightly saline, 0.64 M ha (4 percent) was moderately saline, and an area of 1.1 M ha (7 percent) was strongly saline, whereas miscellaneous land types included 0.94 M ha (6 percent). About 21 percent areas was affected by surface salinity.

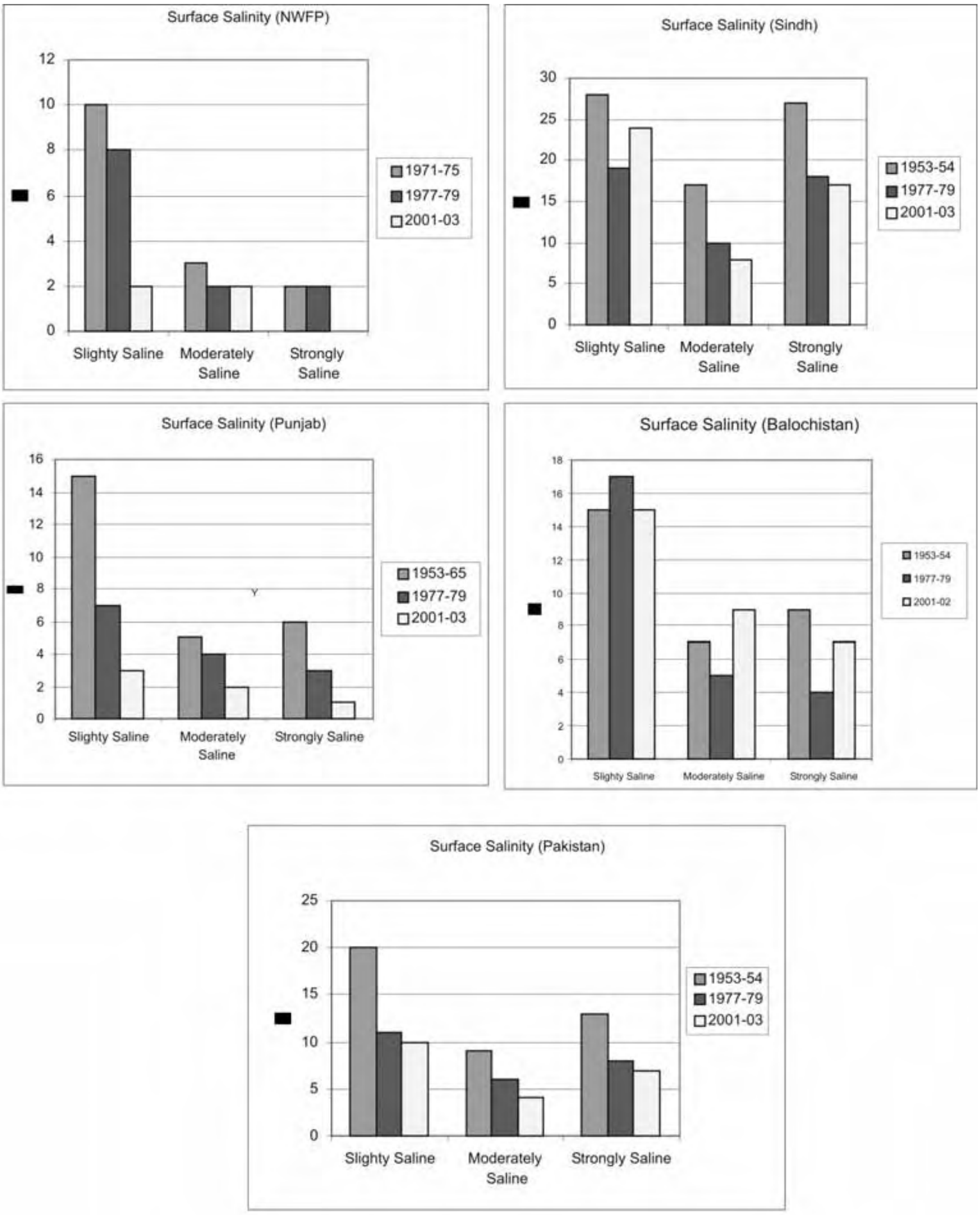


Figure 4. Extent of surface salinity of the Indus Basin during 1953-54, 1977-79, and 2001-03 (in percentage of surveyed area)

Comparison of past surveys indicates that the salt-free lands increased from 56 percent in the early 60's to 72 percent in 1977-79 and 73 percent in 2001-2003. The lands affected by surface salinity have decreased from 42 percent in early 60's to 25 percent in 1977-79 and to 21 percent in 2001-2003.

Profile salinity within 1.5 m depth was surveyed in 1953-65 in Punjab and in 1971-73 in NWFP Province only. The Planning Division, WAPDA in 1977-79, conducted countrywide Profile Salinity Survey. Comparison of profile salinity data shows that profile salinity also decreased in Pakistan as the salt-free profiles increased from 55 percent in 1953-75 to 61 percent in 1977-79 and remained

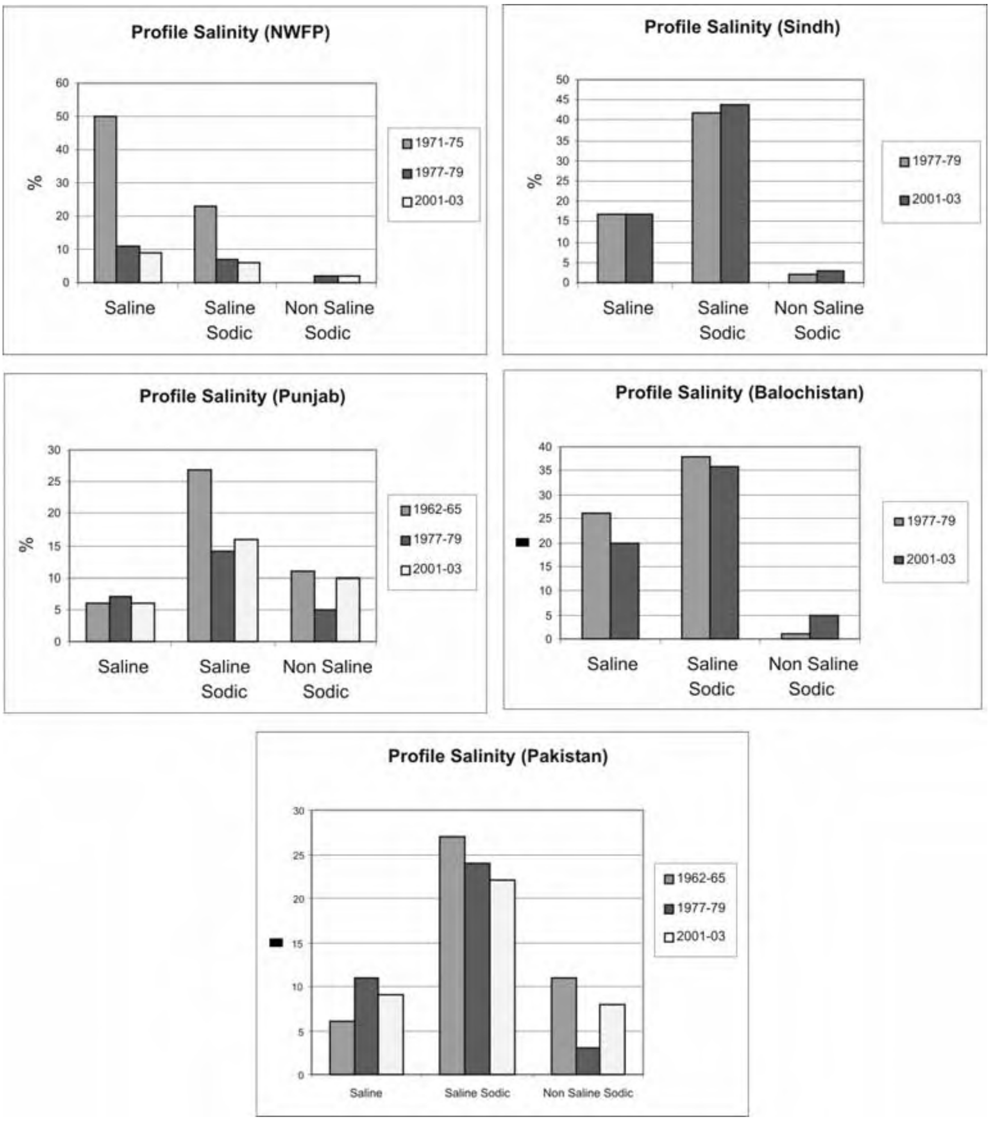


Figure 5. Extent of profile salinity of the Indus Basin during 1977-79 and 2001-03 (in percentage of surveyed area)

unchanged according to latest survey in 2001-03. Saline profiles decreased from 44 percent in 1953-75 to 38 percent in 1977-79 and about 39 percent in 2001-2003.

The reduction in salinity (surface and profile) is primarily due to increased irrigation water supply from surface and groundwater sources, improvement in water management, increased cropping intensity and measures taken by the Government of Pakistan to reclaim the waterlogged and salt-affected lands.

*Salinity Control and Reclamation Project (SCARP) Tube Well Management*

Initially groundwater exploitation was started in the public sector through SCARP tube wells, which has been taken over by the farmers with their own resources. This has reduced the cost of individual well as well as optimized the pumping according to their requirement. Unfortunately a large number of SCARP tube wells still exist in the public sector, most of which are non-functional. A huge amount is spent every year for O&M of these tube wells from the public sector funds. Urgent measures should be taken to transfer these tube wells to farmers.

*Economic and Financial Management*

Water is generally not perceived as an economic good and therefore revenue recovery from the users is only a small proportion of the cost, resulting in both a drain on government finances as well as deterioration in service. There is a need, both to recover cost and to raise the standard of the service in the water sector.

Furthermore, the precious water has traditionally been overused and abused. There is a dire need of educating the public of the real value of water to make the users more conscious about it. This would help in reducing demand, would encourage efficiency of usage, and reduce pressure for unnecessary expansion in certain areas.

To address these issues there is need to:

- Promote appropriate water pricing system to ensure recovery of O&M and capital cost;
- Promote the principle of full cost recovery in providing municipal water supply and sewerage services in urban areas to ensure that the responsible operating agencies are financially viable and are able to provide an efficient service;
- Encourage water metering and effective control over wastage of municipal water;
- In the case of industrial effluent disposal, follow the principle of "polluter pays"; and
- Encourage and involve community organizations to prescribe irrigation charges and to become responsible for collection and imposition of penalties for non-payment.

## Recommendations

Keeping in view the importance of groundwater, its sustainable use is of utmost importance. Therefore, it is necessary to:

- Develop a groundwater regulatory framework to control and optimize groundwater regulation;
- Expedite transition of SCARP tube wells in the public sector to the private sector, and leave development of fresh groundwater to private sector;
- Strengthen monitoring and groundwater modeling to determine sustainable groundwater potential and prepare groundwater budgets for sub-basins and canal commands and to assess the lateral and vertical movement of saline groundwater interface;
- Promote groundwater recharge wherever technically and economically feasible and also rationalize the surface water supplies;
- Delineate areas with falling groundwater table for restricting uncontrolled abstraction;
- Do not temper with dormant saline aquifer overlain by shallow layer of fresh water;
- Reduce water logging and salinity by improved water management practices;
- Encourage the provinces to prepare a groundwater atlas for each canal command and sub-basin. The atlas should delineate:
  (a) Groundwater development potential
  (b) Water quality zones
  (c) Water table depth zones

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