Pakistan

GEOGRAPHY, CLIMATE AND POPULATION

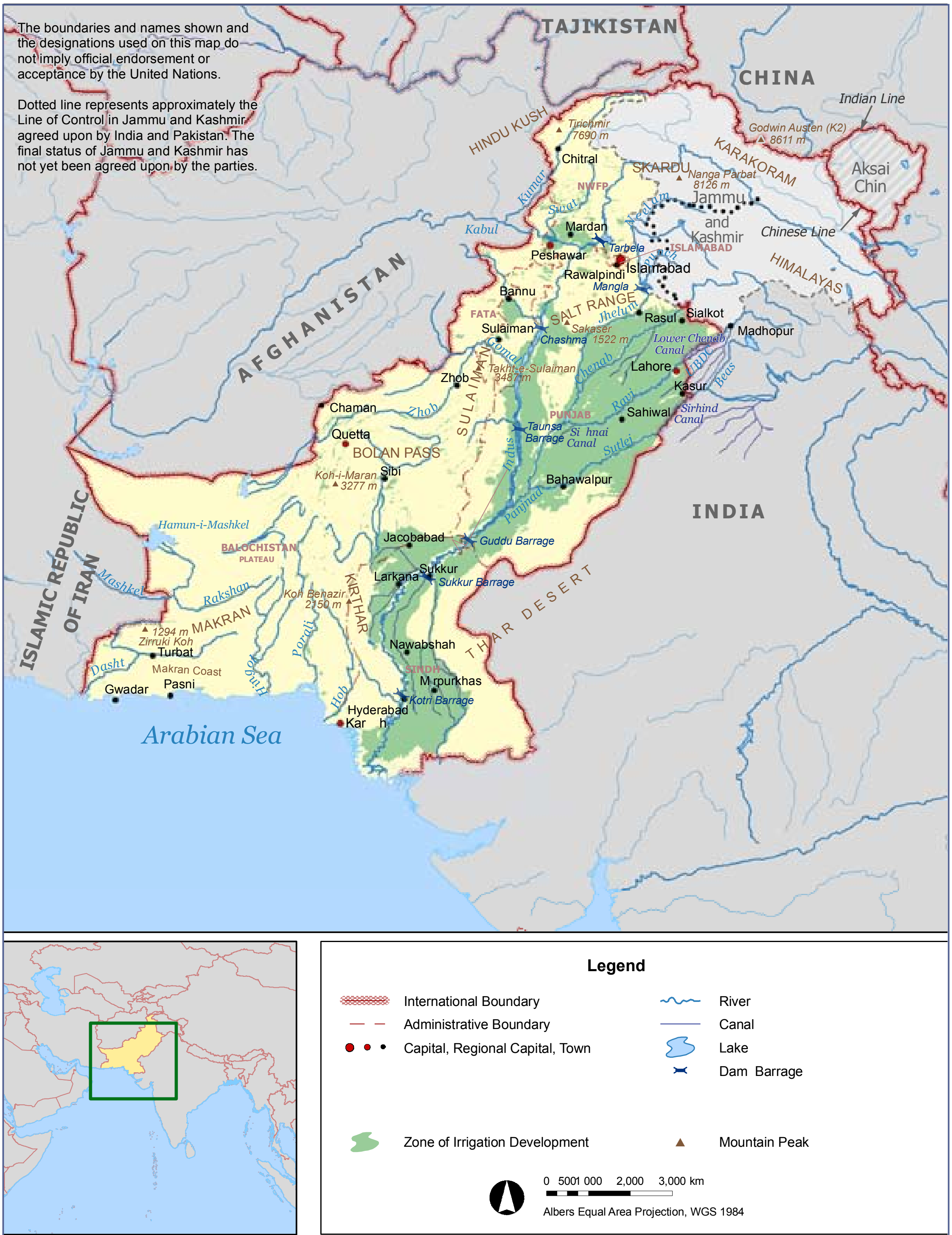
Geography

Pakistan, with a total area of 796 100 km^2, is located in Southern Asia (Table 1). It is bordered by India in the east, China in the northeast, Afghanistan in the north and northwest, the Islamic Republic of Iran in the southwest and the Arabian Sea to the south. Pakistan is divided into four provinces, namely the Punjab, Sindh, Khyber Pakhtunkhwa and Balochistan.

The geography of Pakistan is a profound blend of landscapes varying from plains to deserts, forests, hills and plateaus and ranging from coastal areas of the Arabian Sea in the south to the mountains of the Karakoram range in the north. Pakistan geologically overlaps both with the Indian and the Eurasian tectonic plates, where its Sindh and Punjab provinces lie on the northwestern corner of the Indian plate, while Balochistan and most of Khyber Pakhtunkhwa lie within the Eurasian plate, which mainly comprises the Iranian plateau, some parts of the Near East and Central Asia. Pakistan is divided into four broad geographic areas:

- The Northern Highlands include parts of Hindu Kush, Karakoram and the Himalaya's ranges. Mount Godwin Austen, at 8 611 m in the Himalaya's range, is the second highest peak in the world. The Tirichmir, 7 690 m, is the highest peak in the Hindu Kush range. More than one-half of the summits are over 4 500 m, and more than 50 peaks are over 6 500 m.
- The Pothwar Plateau is bounded on the west by the Indus river, on the north by the Kala Chitta range and the Margalla hills, on the east by the Jhelum river and on the south by the Salt range. The terrain is undulating. The Kala Chitta range rises to an average height of 450-900 m and extends for about 72 km.
- The Indus plain is the valley of the River Indus, a large geographical subdivision of Pakistan. It is bordered on the west by the Iranian plateau (the Sulaiman mountains and the Kirthar range), on the north by the Salt range, and on the east by the Thar desert. The length of the valley along the course of the Indus is about 1 000 km, in Punjab it is about 350 km wide and in lower Sindh it is 200 km. It is subdivided into the trans-Indus plain, the right bank of the Indus, the Thal desert in between the water beds of the Indus and the Jhelum, the Punjab plain, and the Sindh lowlands.
- The Balochistan plateau in the southwest has an average altitude of 600 m and is located at the eastern edge of the Iranian plateau. Dry hills run across the plateau from northeast to southwest. A large part of the northwest is desert. It is geographically the largest of the four provinces having area of 347 190 km^2 comprising 48 percent of the area of Pakistan. The southern region is Makran and the central is Kalat. The Sulaiman mountains dominate the northeast corner with the Bolan pass, which is a natural route into Afghanistan going towards Kandahar. Much of the province south of the Quetta region is sparse desert terrain with pockets of inhabitable towns, mostly near rivers and streams.

The land is mostly used for agriculture and rangelands. In 2009, the total cultivated area was an estimated 21.3 million ha, of which 20.4 million ha (96 percent) for annual crops and 0.9 million ha (4 percent) for permanent crops.



PAKISTAN **FAO - AQUASTAT, 2011**

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TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2009	79 610 000	ha
Cultivated area (arable land and area under permanent crops)	2009	21 280 000	ha
• as % of the total area of the country	2009	27	%
• arable land (annual crops + temp fallow + temp meadows)	2009	20 430 000	ha
• area under permanent crops	2009	850 000	ha
Population			
Total population	2009	170 494 000	inhabitants
• of which rural	2009	64	%
Population density	2009	214	inhabitants/km^2
Economically active population	2009	60 692 000	inhabitants
• as % of total population	2009	36	%
• female	2009	20	%
• male	2009	80	%
Population economically active in agriculture	2009	23 994 000	inhabitants
• as % of total economically active population	2009	40	%
• female	2009	71	%
• male	2009	29	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2009	161 990	million US$/yr
• value added in agriculture (% of GDP)	2009	22	%
• GDP per capita	2008	926	US$/yr
Human Development Index (highest = 1)	2010	0.490	
Access to improved drinking water sources			
Total population	2008	90	%
Urban population	2008	95	%
Rural population	2008	87	%

Climate

Pakistan lies in the subtropical arid zone and most of the country is subjected to a semi-arid climate. Based on physiographic factors and causes of diversity in climate, the country has been classified into four major climatic regions:

1. the marine tropical coastland;
2. the subtropical continental lowlands;
3. the subtropical continental highlands; and
4. the subtropical continental plateau (ADB, 2003).

Water is a critical and limiting resource for the country's sustained economic development. Linked to water, and based on physiography, in 1980 Pakistan was divided into the following agro-ecological zones:

1. Indus delta;
2. southern irrigated plain;
3. sandy desert;
4. northern irrigated plains;
5. Barani (rainfed) areas;
6. wet mountains;

7. western dry mountains;
8. dry western plateau; and
9. Sulaiman Piedmont (Ahmad, 2004a).

June is the hottest month on the plains and July in the mountainous areas, with temperatures over 38 °C, while the mean monthly minimum is only 4 °C in December/January. The average annual precipitation is around 494 mm, but is unevenly distributed. It varies from less than 100 mm in parts of Balochistan and Sindh provinces to more than 1 500 mm in the foothills and northern mountains of Punjab and Khyber Pakhtunkhwa. The mean Rabi season rainfall (October to March) varies from less than 50 mm in parts of Sindh province to more than 500 mm in Khyber Pakhtunkhwa. The mean Kharif season rainfall (April to September) varies from less than 50 mm in parts of Balochistan to more than 800 mm in the northern Punjab and Khyber Pakhtunkhwa.

About 60 percent of the rainfall in the monsoonal climate is received from July to September. The extreme variability in seasonal rainfall directly affects river flows, which vary considerably during the Rabi and the Kharif seasons. In the northern areas, at altitudes of more than 5 000 m, snowfall exceeds 5 000 mm/year and provides the largest resource of water in the glaciated zone. Around 92 percent of the country's area is classified as semi-arid to arid, facing extreme shortage of precipitation. Most of the irrigated area is classified as semi-arid to arid. The reference crop evapotranspiration varies from 1 150 to 1 800 mm/year (Ahmad, 2008a).

Population

In 2009, the total population was 170 million, of which around 64 percent lived in rural areas (Table 1). The average population density is 214 inhabitants per km^2, with the population being concentrated on the Indus plain. The population density in the Balochistan plateau is extremely low because of the mountainous terrain and scarcity of water. Average annual population growth during the period 1999-2009 was an estimated 1.9 percent.

In 2008, access to improved drinking water sources reached 90 percent (95 and 87 percent for the urban and rural population respectively). Sanitation coverage was 45 percent (72 and 29 percent for urban and rural population respectively).

ECONOMY, AGRICULTURE AND FOOD SECURITY

The total population economically active in agriculture was an estimated 24.0 million, which was 40 percent of the economically active population. About 29 percent of the population economically active in agriculture are women. In 2009, GDP was US$161 990 million of which agriculture accounted for 22 percent (Table 1).

The roles of men and women are sharply defined, but women are actively involved in farming. Women are largely responsible for livestock production and maintenance, picking cotton, transplanting rice, harvesting and threshing other crops.

In 2007, the overall unemployment rate was 5.2 percent of the total labour force, out of which 4.7 percent of rural labour and 6.3 percent of urban labour is unemployed. There is an increase in the number of severely food-insecure people, from 23 percent in 2005-2006 to 28 percent in 2008. Food security in 2007-2008 had significantly worsened as a result of food price hikes. The total number of households falling into this category in 2008 was around 7 million; equal to about 45 million people. In relative terms, the increase is more pronounced in rural areas, where food expenditure rose by 10 percent and total expenditure by 4 percent (GoP, 2008b).

Food exports account for 13.2 percent of total exports, or US$2 050 million, contributing 26.1 percent to overall export growth. Rice accounting for 60 percent, has registered an impressive growth of 28.5 percent. Pakistan clearly benefited from the unprecedented rise in the international price of rice. Since Pakistan is a net exporter of rice, it is likely to benefit from the elevated international price of rice in coming years. This will encourage farmers in Pakistan to grow more rice and benefit from the higher prices on the international market. Other important foods registered impressive growth, such as fruits, oilseeds, nuts and kernels, meat and fish. More than a 67 percent increase in imports is attributed to wheat, followed by 47 percent for edible oil (GoP, 2008a; GoP, 2008b).

WATER RESOURCES AND USE

Water resources

Pakistan can be divided into three hydrological units:

- The Indus basin covers more than 520 000 km^2, or 65 percent of the territory, comprising all the provinces of Punjab, Sindh and Khyber Pakhtunkhwa and the eastern part of Balochistan. The Indus river has two main tributaries, the Kabul on the right bank and the Panjnad on the left bank. The flow of the Panjnad results from five main rivers (literally Punjab means 'five waters'): the Jhelum and Chenab, known as the western rivers, and the Ravi, Beas and Sutlej, known as the eastern rivers.
- The Karan desert in the west of Balochistan, western Pakistan, is an endorheic basin covering 18 percent of the territory. The Mashkel and Marjen rivers are the principal source of water in the basin. The Marjen is a minor tributary to the Mashkel. The water is discharged into the Hamun-i-Mashkel lake in the southwest, on the border with the Islamic Republic of Iran.
- The arid Makran coast, along the Arabian Sea, covers17 percent of the territory in its southwestern part (Balochistan province). The Hob, Porali, Hingol and Dasht are the principal rivers in this coastal zone.

The flows in the river basins outside the Indus Basin Irrigation System (IBIS), the Makran coast and the Karan closed basin, are flashy in nature and do not have a perennial supply. They account for a total flow inferior to 5 km^3 per year.

The long-term average annual precipitation for Pakistan is 494 mm, representing 393.3 km^3 (Table 2). Precipitation in 2008 was 278 mm. Internally produced surface water is 47.4 km^3/year, whereas internally generated groundwater is 55.0 km^3/year. Some of the groundwater drains directly into the sea, while the rest feeds the base flow of the river system, which is an estimated 47.4 km^3/year. Taking into account this overlap of 47.4 km^3/year between surface water and groundwater, the internal renewable water resources (IRWR) are an estimated 55 km^3/year.

River flows are composed of glacier melt, snowmelt, rainfall and runoff. The Indus basin has a total drainage area of 1.1 million km^2, of which 47 percent lies in Pakistan, and the other 53 percent in China, Afghanistan and India. Because of the importance of irrigation on the Indus plain, the water balance of the Indus basin has been carefully studied, which is not the case for the other basins. Most results found, therefore, refer only to the Indus basin. The mean annual inflow into the country through the Indus river system is an estimated 265.08 km^3, of which 21.5 km^3 is from the Kabul river and other tributaries of the Indus river flowing from Afghanistan, 11.1 km^3 from the eastern rivers of the Indus basin and 232.48 km^3 from the western rivers, both flowing from India.

Under the Indus Water Treaty (1960) between India and Pakistan, it is estimated that 170.27 km^3/year is reserved for inflow from India into Pakistan. The following rules apply:

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	494	mm/yr
	-	393 300	million m^3/yr
Internal renewable water resources (long-term average)	-	55 000	million m^3/yr
Total actual renewable water resources	-	246 800	million m^3/yr
Dependency ratio	-	78	%
Total actual renewable water resources per inhabitant	2009	1 474	m^3/yr
Total dam capacity	2005	23 360	million m^3
Water withdrawal			
Total water withdrawal	2008	183 421	million m^3/yr
- irrigation + livestock	2008	172 371	million m^3/yr
- municipalities	2008	9 650	million m^3/yr
- industry	2008	1 400	million m^3/yr
• per inhabitant	2008	1 096	m^3/yr
Surface water and groundwater withdrawal	2008	183 421	million m^3/yr
• as % of total actual renewable water resources	2008	74	%
Non-conventional sources of water			
Produced wastewater	2000	12 330	million m^3/yr
Treated wastewater	2000	145	million m^3/yr
Reused treated wastewater		-	million m^3/yr
Desalinated water produced		-	million m^3/yr
Reused agricultural drainage water		-	million m^3/yr

- *Eastern Rivers:* All the waters of the eastern tributaries of the Indus river originating in India, i.e. the Sutlej, Beas and Ravi rivers taken together, shall be available for unrestricted use by India. Pakistan shall be under an obligation to let flow, and shall not permit any interference with, the waters (while flowing in Pakistan) of any tributary which in its natural course joins the Sutlej main or Ravi main before these rivers have finally crossed into Pakistan. This average annual flow in India before crossing the border is an estimated 11.1 km^3. All the waters, 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.
- *Western Rivers:* Pakistan shall receive for unrestricted use all those waters of the western rivers, i.e. Chenab and Jhelum, which India is under obligation to let flow, except for restricted uses, related to domestic use, non-consumptive use, agricultures use and generation of hydroelectric power of which the amounts are set out in the Treaty. Annual flow from China to India in the Indus basin is 181.62 km^3 and it is estimated that the flow generated within India is 50.86 km^3, resulting in a flow from India to Pakistan in this part of 232.48 km^3, of which 170.27 km^3 reserved for Pakistan and 62.21 km^3 available for India.

Given the seasonal nature of the Himalayan runoff, roughly 85 percent of the annual flows are in the *Kharif* season (summer), and only 15 percent in the *Rabi* season (winter).

The Indus basin has a large groundwater aquifer covering a gross command area of 16.2 million ha.

In 2005, the total dam capacity was an estimated 23.36 km^3 (Table 2). Currently, there are three large hydropower dams and 50 smaller dams (no more than 15 m high), while 11 smaller dams are under construction.

The designed live storage capacity of the three large hydropower dams in the Indus basin is 22.98 km^3 (Tarbela 11.96 km^3, Raised Mangla 10.15 km^3, which includes recent raising of 3.58 km^3, and Chashma 0.87 km^3). The current live storage capacity of these three large hydropower dams is 17.89 km^3, representing an overall loss of storage of 22 percent (World Bank, 2005). Pakistan can barely store 30 days of water in the IBIS. Each km^3 of storage capacity lost means 1 km^3/year less water that can be supplied with a given level of reliability. There is an urgent need for storage just to replace capacity that has been lost as a result of sedimentation. Given the high silt loads from the young Himalayas, two large reservoirs are silting rapidly. In 2008, because of the raising of the Mangla dam, the loss owing to sedimentation was recovered (WB, 2005).

The designed live storage capacity of 50 small dams is 0.383 km^3. The information related to sedimentation and loss of live storage of small dams is not available. It was assumed, therefore, that on average 25 percent of the live storage in these small dams has been lost as a result of sedimentation.This has lead to the current live storage capacity of these small dams of 0.287 km^3. There are more than 1 600 mini dams (less than 15 m high), which were constructed for small-scale irrigation, but the capacity of these mini dams is low because they are usually constructed for an individual farmer. The information on the live storage capacity of mini dams is not available. Storage of mini dams is negligible compared to that of small dams. According to certain estimates, the total designed capacity of these mini dams would be around 0.036 km^3.

Pakistan has a hydroelectric potential of about 50 000 MW, when the whole of Chitral as well as Skardu gorges are comprehensively assessed. The Indus river and its tributaries are the main source of water. Its main gorge, between the Skardu and Tarbela, has a potential of almost 30 000 MW. These include Bashan (4 500 MW), Disso (3 700 MW), Banjo (5 200 MW), Thicket (1 043 MW), Paten (1 172 MW), Racicot (670 MW), Yuba (710 MW), Hugo (1 000 MW), Tunas (625), and Sakardu or Kithara (possibly 4 000 to 15 000 MW). Almost 20 000 MW potential is available on various sites on the rivers: Swat, Jhelum, Neelam, Punch and Kumar (Qazilbash, 2005).

In 2000, the total wastewater produced was an estimated 12.33 km^3, while treated wastewater was an estimated 0.145 km^3.

International water issues

The Indus Water Treaty (1960) between India and Pakistan, described earlier, helped to resolve the issues between these two countries and allowed Pakistan to have large investments in the Indus Basin Project (IBP) during the 1960s to construct a network of canals and barrages to divert water from the western rivers to the command of the eastern rivers as replacement works. In the last few years, however, Pakistan has objected to India's development of the of hydropower projects on the western rivers, Chenab and Jhelum.

Water use

Agriculture withdrew an estimated 172.4, or 94 percent of the total water withdrawal. Municipal and industrial water withdrawal was an estimated 9.7 km^3 and 1.4 km^3, respectively (Figure 1) (GoP, 2008a; Zakria, 2000).

Total water withdrawal in 2008 was an estimated 183.4 km^3. Surface water withdrawal accounts for 121.8 km^3 (66.4 percent) and groundwater withdrawal accounts for 61.6 km^3 (33.6 percent). This mainly refers to the IBIS, the withdrawal outside the IBIS being extremely small (GoP, 2008a) (Table 2 and Figure 2).

Most summer rains are not available for crop production or recharge to groundwater because of rapid runoff of torrential showers.

FIGURE 1
Water withdrawal by sector
Total 183.421 km³ in 2008

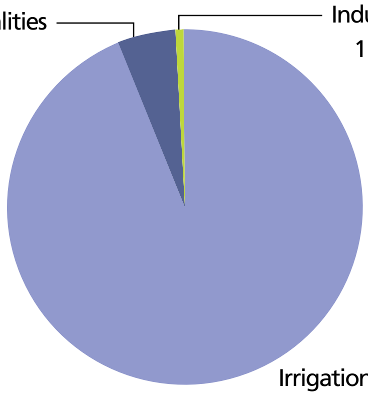
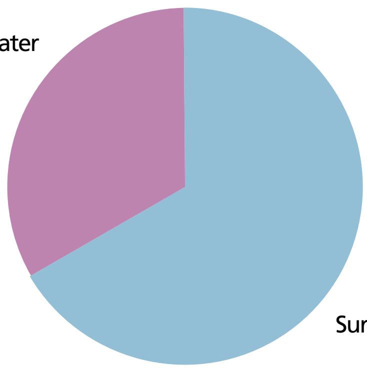


FIGURE 2
Water withdrawal by source
Total 183.421 km³ in 2008



The overall irrigation efficiency in the IBIS is 40 percent (canal efficiency 75 percent, conveyance efficiency 70 percent and field application efficiency 75 percent). The water lost during conveyance and application largely contributes towards recharging groundwater.

In some areas, development appears to have reached the point where groundwater is being mined. Most urban and rural water is supplied from groundwater. Over 50 percent of the village water supply is obtained from hand pumps, which are installed by private households. In saline groundwater areas, irrigation canals are the main source of municipal water.

Groundwater is pumped using electricity and diesel fuels. There are currently one million tubewells, of which 87 percent are operated by diesel. Power failures, extended load shedding and poor electricity supply are the main reasons for the slow growth of electric tubewells compared to diesel-operated tubewells (Ahmad, 2008b).

Information on the use of treated wastewater and desalinated water is not available, it is however a minor fraction of the total. Sewage water from urban areas is used by farmers in the peri-urban areas to irrigate fodder crops and vegetables. Farmers also reuse drainage water during periods of water scarcity to supplement canal water supplies, but data are not available.

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

The irrigation potential of land and water resources is estimated to be equal to the cultivable area, or 21.3 million ha. In 2008, the area equipped for irrigation was around 19.99 million ha, compared with 15.73 million ha in 1990. The total water managed area is an estimated 21.24 million ha, compared with 16.96 million ha in 1990, and can be divided according to the following classification (Table 3):

- Full control irrigation schemes cover 19.27 million ha, of which 14.87 million ha within the IBIS and 4.40 million ha outside the IBIS. The areas outside the IBIS cover minor perennial irrigation schemes, groundwater schemes including tubwells, wells, *karezes* and springs. They are located in Khyber Pakhtunkhwa and Balochistan. In Khyber Pakhtunkhwa irrigation is carried out using pump lifts, which are maintained by the Provincial Irrigation Department (PID). In the northern parts of Khyber Pakhtunkhwa contour channels are used to irrigate, offtaking water from the locally available sources, which are often steep sided streams or springs. Most of these schemes are owned and operated directly by the beneficiaries through traditional social organizations. In Balochistan irrigation water is taken from *karezes* and perennial springs. (*Karezes* are tunnels or underground channel that tap an aquifer). Irrigation schemes are generally small, ranging between 50 and 400 ha, and operated by a group. . Some small, group-operated schemes, are irrigated from infiltration galleries or small weirs in rivers and individuals may pump water from tubewells and open wells.

- Spate irrigation in 2004 covered a total potential area of 2 million ha (1.4 million ha in 1990). This area refers to potential spate area, but actual area varies based on flood occurrence and frequency and is around 0.72 million ha in an average year. In Pakistan, these areas are known as *Rod Kohi* in Khyber Pakhtunkhwa and Punjab, or *Bandat* in Balochistan, and the irrigation method is often called flood irrigation. The streams on the Makran coast and the Karan closed basin are flashy in nature and do not have a perennial supply, thus about 25 percent of their flow, which is less than 5 km^3, is used for spate irrigation. This kind of irrigation relies on floods from hill torrents. Wherever possible, the runoff is harnessed for irrigation by weirs or temporary diversion structures. Farmers divert the spate flow onto their fields by constructing breachable earth bunds (called *gandas*) across the rivers, or by constructing stone/gravel spurs leading towards the centre of the river. Captured water flows from field-to-field and, when the soil profile is saturated, the lower bund is breached to release water into another field. Annual average cropping intensity is 20 percent.
- Flood recession cropping areas cover 1.25 million ha on 2004 (1.23 million ha in 1990). In Pakistan these areas are known as *Sailaba*, and are often called falling flood irrigation areas. Sailaba cultivation is carried out on extensive tracts of land along the rivers and hill streams subject to annual inundation. Moisture retained in the root zone is utilized after the flood subsides together with subirrigation resulting from the capillary rise of groundwater and any rain.

Apart form these water managed areas, some attempts have been made to develop water harvesting, which is known in Pakistan as *Khushkaba*, though it is not possible to quantify this area.

In 2008, out of the 19.27 million ha of full control irrigation schemes, 6.91 million ha were commanded by surface water (canals), 4.13 million ha by groundwater (wells, tubewells), whereas 7.96 million ha were commanded by both surface water and groundwater. Only 0.27 million ha were commanded by non-conventional sources of water (Figure 3). Surface irrigation is the only irrigation technique used. In 2008, the entire area equipped for full control irrigation was actually irrigated.

In 2008, small schemes (< 100 ha) covered 21.4 percent of the total area equipped for full control irrigation, medium-size schemes (100-25 000 ha) 2.3 percent and large schemes (> 25 000 ha) 76.3 percent (Figure 4).

The Indus Basin Irrigation System

Although irrigation takes place in other areas of Pakistan, information on the history and development of irrigation generally refers to the IBIS, where more than 95 percent of the irrigation is located.

The 4 000 year old Indus civilization has its roots in irrigated agriculture. Canal irrigation development began in 1859 with the completion of the Upper Bari Doab Canal (UBDC) from Madhopur headworks (now in India) on Ravi river. Until that time, irrigation was undertaken through a network of inundation canals, which were functional only during periods of high river flow. These provided water for *Kharif* (summer) crops and residual soil moisture for *Rabi* (winter) crops. The last inundation canals were connected to weir-controlled supplies in 1962 with the completion of the Guddu barrage on Indus river (barrages in the IBIS are constructed to divert river water into canals and the storage capacity is insignificant).

TABLE 3
Irrigation and drainage

Irrigation potential			21 300 000	ha
Irrigation				
1. Full control irrigation: equipped area		2008	19 270 000	ha
- surface irrigation		2008	19 270 000	ha
- sprinkler irrigation		2008	0	ha
- localized irrigation		2008	0	ha
• % of area irrigated from surface water		2008	35.9	%
• % of area irrigated from groundwater		2008	21.4	%
• % of area irrigated from mixed surface water and groundwater		2008	41.3	%
• % of area irrigated from mixed non-conventional sources of water		2008	1.4	%
• area equipped for full control irrigation actually irrigated		2008	19 270 000	ha
- as % of full control area equipped		2008	100	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)			-	ha
3. Spate irrigation		2008	720 000	ha
Total area equipped for irrigation (1+2+3)		**2008**	**19 990 000**	**ha**
• as % of cultivated area		2008	94	%
• % of total area equipped for irrigation actually irrigated			-	%
• average increase per year over the last 7 years		2001-2008	1.66	%
• power irrigated area as % of total area equipped			-	%
4. Non-equipped cultivated wetlands and inland valley bottoms			-	ha
5. Non-equipped flood recession cropping area		2004	1 250 000	ha
Total water-managed area (1+2+3+4+5)		**2008**	**21 240 000**	**ha**
• as % of cultivated area		2008	100	%
Full control irrigation schemes	**Criteria**			
Small-scale schemes	< 100 ha	2008	4 130 000	ha
Medium-scale schemes		2008	440 000	ha
Large-scale schemes	> 25 000 ha	2008	14 700 000	ha
Total number of households in irrigation			-	
Irrigated crops in full control irrigation schemes				
Total irrigated grain production (wheat and barley)			-	metric tons
• as % of total grain production			-	%
Harvested crops				
Total harvested irrigated cropped area		2008	21 451 674	ha
• Annual crops: total		2008	20 656 701	ha
- Wheat		2008	7 334 600	ha
- Rice		2008	2 515 400	ha
- Maize		2008	946 530	ha
- Millet		2008	477 540	ha
- Sorghum		2008	253 260	ha
- Barley		2008	81 990	ha
- Potatoes		2008	154 317	ha
- Pulses		2008	1 006 441	ha
- Vegetables		2008	352 656	ha
- Tobacco		2008	51 398	ha
- Cotton		2008	3 054 300	ha
- Fodder		2008	2 459 500	ha
- Groundnuts		2008	9 012	ha
- Sunflower		2008	397 306	ha
- Sesame		2008	69 915	ha
- Rapeseed		2008	201 600	ha
- Sugarcane		2008	1 241 300	ha
- Other annual crops		2008	49 636	ha
• Permanent crops: total		2008	794 973	ha
- Citrus		2008	199 369	ha
- Bananas		2008	35 558	ha
- Other permanent crops		2008	560 046	ha
Irrigated cropping intensity (on area actually irrigated)		2008	111.3	%

TABLE 3
Irrigation and drainage (continued)

Drainage - Environment			
Total drained area	2008	15 140 000	ha
- part of the area equipped for irrigation drained	2008	15 140 000	ha
- other drained area (non-irrigated)	2008	0	ha
• drained area as % of cultivated area	2008	71	%
Flood-protected areas		-	ha
Area salinized by irrigation	2004	7 003 000	ha
Population affected by water-related diseases		-	inhabitants

FIGURE 3
Source of irrigation water on area equipped for full control irrigation
Total 19 270 000 ha in 2008

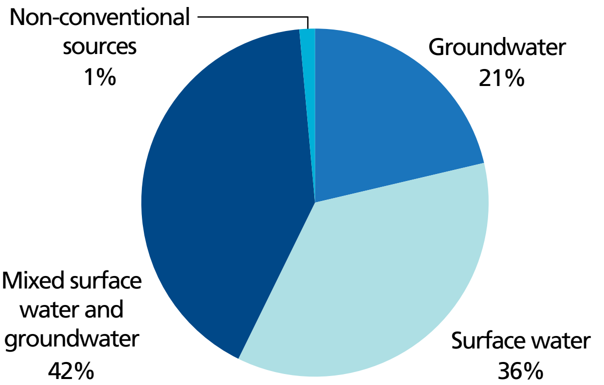
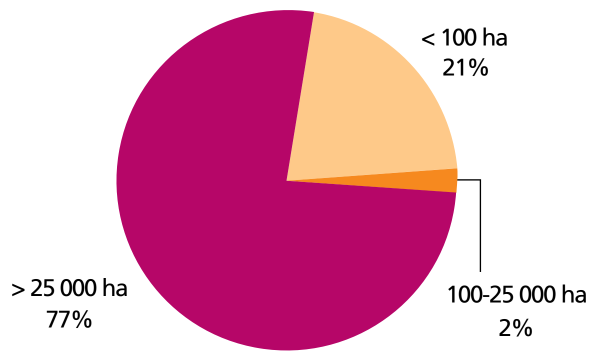


FIGURE 4
Type of full control irrigation schemes
Total 19 270 000 ha in 2008



UBDC was followed by Sirhind canal from Rupar headworks on Sutlej in 1872 (also in India) and Sidhnai canal from Sidhnai barrage on Ravi in 1886. The Lower Chenab from Khanki on Chenab in 1892, and Lower Jhelum from Rasul on Jhelum in 1901 followed. Lower and Upper Swat, Kabul river and Paharpur canals in Khyber Pakhtunkhwa were completed during 1885 to 1914.

In the beginning of the 1900s, it became apparent that the water resources of the individual rivers were not in proportion to the potential irrigable lands. Ravi river, serving a large area of Bari Doab, was low in supply while Jhelum had a surplus. An innovative solution was developed in the form of the Triple Canal Project, 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. The Triple Canal Project was a land-mark in integrated inter-basin water resources management and provided the key concept for the resolution of the Indus waters dispute between India and Pakistan in 1960.

The Sutlej Valley Project, comprising four barrages and two canals, was completed in 1933. This resulted in the development of the unregulated flow resources of the Sutlej river and motivated planning for the Bhakra reservoir (now in India). During the same period, the Sukkur barrage and its system of seven canals, serving 2.95 million ha in the Lower Indus, were completed. These are considered to be the first modern hydraulic structures on the downstream Indus river. Haveli and Rangpur from Trimmu headworks on Chenab in 1939 and Thal canal from Kalabagh headworks on the Indus were completed in 1947. This comprised the system inherited by Pakistan at the time of its creation in 1947.

At independence, the irrigation system, conceived originally as a whole, was divided between India and Pakistan without considering the irrigated boundaries. This resulted in the creation of an international water dispute in 1948, which was finally resolved by the enforcement of the Indus Water Treaty in 1960 under the aegis of the World Bank. The Indus Basin Project (IBP) including Mangla dam, five barrages, one syphon and eight inter-river link canals, was completed during 1960-1971, while Tarbela dam started partial operation in 1975-1976.

After the partition, Kotri, Taunsa and Guddu barrages were completed on the Indus river to provide controlled irrigation to areas previously served by inundation canals. The Taunsa barrage was completed in 1958 to divert water to two large areas on the left and right banks of the river. This made irrigated agriculture possible for about 1.18 million ha of arid landscape in Punjab province. Currently rehabilitation and modernization of the barrage is in progress. Also, three additional inter-river link canals were built prior to the initiation of the IBP.

As a result of these extensive developments Pakistan now possesses the world's largest contiguous irrigation system. It commands 14.87 million ha (2008) and encompasses the Indus river and its tributaries including three large reservoirs (Tarbela, Mangla, and Chashma), 23 barrages/headworks/siphons, 12 inter-river link canals and 45 canals commands extending for 60 800 km with communal watercourses, farm channels, and field ditches covering another 1.6 million km to serve over 90 000 farmer-operated watercourses. In the Indus system, river water is diverted by barrages and weirs into main canals and subsequently branch canals, distributaries and minors.

The flow to the farm is delivered by over 107 000 watercourses, which are supplied through outlets *(moghas)* from the distributaries and minors. The *mogha* is designed to allow a discharge that self-adjusts to variations in the parent canal. Within the watercourse command (an area ranging from 80 to 280 ha), farmers receive water proportional to their land holding. The entire discharge of the watercourse is given to one farm for a specified period on a seven day rotation. The rotation schedule, called *warabandi*, is established by the Provincial Irrigation and Power Department, unless the farmers can reach a mutual agreement.

Role of irrigation in agricultural production, economy and society

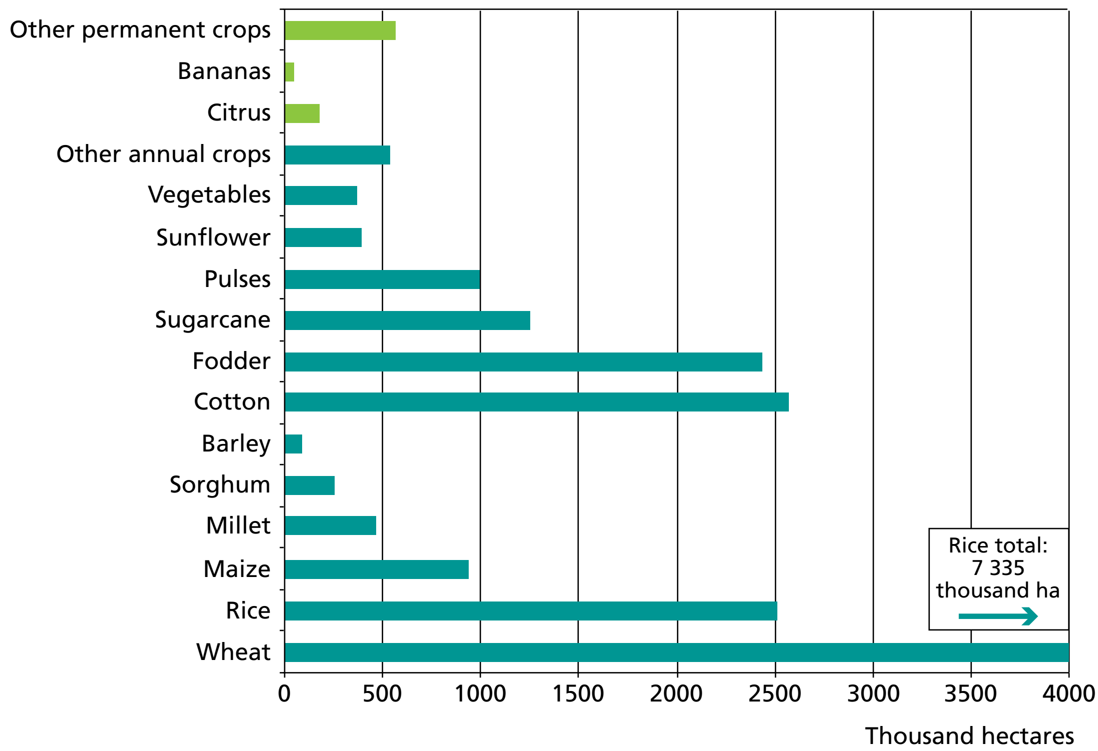
All cotton, rice, sugarcane, fodder, maize grain, fruits, vegetables, freshwater fisheries, dairy livestock are grown under irrigated conditions, and 90 percent of the wheat area is irrigated. Coarse grains, pulses, groundnut, sorghum and millets are normally rainfed or spate irrigated. Around 10 percent of the wheat area is rainfed,contributing only 5 percent of wheat production. Wheat, pulses and coarse grains are spate irrigated. Recession agriculture is also practiced around the rivers and streams during floods; after receding of floodwater the crops are grown.

In 2008, the total harvested irrigated cropped area was about 21.45 million ha (Table 3 and Figure 5). The major irrigated crops are wheat, rice, sugarcane, cotton and fodder. These crops are almost 78 percent of the total harvested area and consume 82 percent of the total available water resources. The area under these crops is 16.60 million ha, of which 7.33; 2.52; 1.24; 3.05 and 2.46 million ha for wheat, rice, sugarcane, cotton and fodder, respectively (GoP, 2008a).

Full control irrigated agriculture provides 90 percent of wheat and small grains besides nearly 100 percent of sugarcane, rice, cotton, fruits and vegetables, whereas the *Barani* (rainfed) and *Sailaba* (spate irrigation) areas contribute only 10 percent of wheat and a portion of small grains and pulses. It also provides milk, meat and fuelwood besides crops (Ahmad, 2004a; Ahmad, 2004b; Ahmad, 2008a; GoP, 2008b). The average yield of irrigated wheat, rice, sugarcane, cotton and fodder is 2.5, 2.2, 51.5, 0.65 and 22.4 tonnes/ha respectively (GoP, 2008a).

In 2008, the average cost of irrigation development in public schemes was an estimated US$1 300/ha, while the cost of drainage development was aroundUS$2 650/ha. The average cost of operation and maintenance (O&M) is US$65/ha per year. The average cost of sprinkler and irrigation for on-farm installation is US$1 500/ha and US$1 750/ha respectively.

FIGURE 5
Irrigated crops on area equipped for full control irrigation
Total harvested area 21 451 674 ha in 2008 (cropping intensity on full control equipped area: 111.3%)



Status and evolution of drainage systems

When the IBIS was developed, the drainage needs were initially minimal. Water tables were deep and irrigation water supplies were too low to generate much groundwater recharge and surface water losses. Whatever little drainage was required, could readily be accommodated by the existing natural drainage. The drainage needs, however, have increased as more irrigation water has been diverted and the water table has risen to harmful levels causing waterlogging and salinity. The drainage systems were developed over the last 30-40 years (Bhutta and Smedema, 2005).

Drainage and reclamation programmes to mitigate waterlogging and salinity, especially in areas where the water table is 0-1.5 m deep, have been assigned priority. Under the Salinity Control and Reclamation Projects (SCARPs), a disastrous area of 1.97 million ha (with a water table at 0-1.5 m) was reclaimed through rehabilitation of existing drains and investments for the new drainage schemes. Surface drains were also constructed in areas where surface runoff resulted from rainfall or excess irrigation. To encourage private sector participation in drainage, SCARP tubewells were transferred from the public to private sector. Tile drainage was given due attention. The current situation of the waterlogged area shows that the area at risk (with a water table at less than 1.5 m) comprises 12 percent of the total irrigated area. About 1.06 million ha of this area at risk has been covered under various SCARPs. During the current decade, an area of 1.21 million ha was reclaimed under drainage projects such as LBOD, RBOD-I, II and III, Drainage-IV and the National Drainage Programme with the installation of 1 260 drainage wells, transitioning of 5 000 public tubewells, construction or rehabilitation of 2 200 km of open drains, and laying of tile drainage system in 146 500 ha (MTDF 2005).

In 2008, the total drained area equipped for irrigation, was approximately 15.14 million ha.

WATER MANAGEMENT, POLICIES AND LEGISLATION RELATED TO WATER USE IN AGRICULTURE

Institutions

Water is a federal subject, for which the following federal institutions are responsible:

- The Ministry of Water and Power is responsible for the development of water projects including hydropower dams, main canals and inter-provincial works. The Ministry is supported by the Office of the Chief Engineering Advisor, the Chair of the Federal Flood Commission and the Chair of the Indus River System Authority (IRSA).
- The IRSA is responsible for the distribution of water among the provinces and assists provinces to share shortages according to the Apportionment Accord of 1991.
- The Water and Power Development Authority (WAPDA), created in 1958 as a semiautonomous body, is the functional arm of the Ministry of Water and Power and is responsible for the development of hydropower and water development projects.
- The Ministry of Food and Agriculture is responsible for water management at the watercourse command level and farm level irrigation and water productivity. The Ministry is supported by the Federal Water Management Cell, which coordinates the national projects and provides services to the provinces for planning, evaluation and monitoring of Mega projects. This Cell also provides support to the provincial Departments of Agriculture through the provincial On-Farm Water Management (OFWM) Directorate Generals. These OFWMs implement the programmes and projects related to water management for agriculture and are involved in organizing water user associations at the watercourse level and their federations at the distributary canal command level.
- The Pakistan Agricultural Research Council (PARC) is a national apex research organization responsible for research in agriculture, land, water, energy, environment and livestock.
- The Water Resources Research Institute of the National Agricultural Research Centre of PARC is a major institution dealing with research related to water for agriculture. Recently, the federal government transferred the *High Efficiency Irrigation Project,* which is a mega project, to PARC under the directive of the Prime Minister of Pakistan.
- Pakistan Council of Research in Water Resources is an organization under the federal Ministry of Science and Technology. The Council is also involved in some areas of water research related to agriculture, but has no formal link to the Department of Agriculture in the provinces. Its activities are related to water for domestic use, water quality and control of desertification.

Irrigation and drainage are handled at the provincial level. The Provincial Irrigation and Drainage Authorities (PIDAs) are the custodians of the irrigation networks in association with the Area Water Boards (AWB). These institutions carry out O&M and the distribution of water within the province and to design and develop new irrigation and drainage schemes. The PIDA experiment is still in its infancy, the Provincial Irrigation Departments (PIDs) are still active, as the responsibility and authority has not yet been transferred to the AWBs.

The Farmers' Organizations (FOs) were registered during the early twentieth century. The Institutional Reforms for the water sector, the Provincial Irrigation and Drainage Authority Acts authorized the PIDAs to form and register the FOs at the distributary canal level. At the provincial level the FOs have been established in the selected AWBs. The FOs are responsible for collecting the water fee.

Along with the FOs, the first Water User Associations (WUA) were created in 1981 under the World Bank-supported *On-Farm Water Management Programme.* These were formed at the watercourse level, with the primary objective of rehabilitating the watercourses. Currently around 80 000 WUAs have been formed that have participated in the rehabilitation and lining of the watercourses.

Environment institutions have been established within most of the organizations besides the federal and provincial Environmental Protection Agencies (EPAs) to address issues related to field level activities. The regulatory and legal aspects of pollution control are being implemented by the EPAs.

Water management

The government of Pakistan has undertaken a *National Project on the Improvement of Watercourses* to improve 88 000 watercourses costing Pakistani Rupees 66 billion (about US$0.8 billion in 2009) and cost sharing of 70:30 percent, where 70 percent is contributed jointly by the federal and provincial governments and 30 percent by farmers. Since 2007 the federal government has been funding a *National Programme for Water Conservation for Productivity Enhancement using High Efficiency Irrigation System.* A subsidy of Pakistani Rupees 90 000/ha (US$1 070/ha in 2009) is provided jointly by the federal and provincial governments and the rest by the farmer. Private sector service and supply companies have been registered in to provide 'turn-key' installation of sprinkler and drip irrigation systems. Recently, this project has been transferred to PARC owing to the extremely slow progress.

The public sector operates the irrigation systems above the *moghas* (turnout). Each season, the Water and Power Development Authority (WAPDA) of the Federal Government estimates water availability for the following season. The Provincial Irrigation Departments (PID) inform the WAPDA of provincial water demands at specific locations. The WAPDA releases water from the reservoirs to meet demands as closely as possible. The limited reservoir capacity of the systems does not allow the full regulation of rivers for irrigation.

Farmers use groundwater to irrigate their fields at peak demand owing to scarcity of water and shortages imposed resulting from fixed rotation and the continuous flow irrigation system, which is too rigid to meet crop-water demands. The water distribution system is based on a rotation schedule, called *Warabandi* (7-10 days rotation), and water is supplied equitably to farmers on a fixed rotation; inequity arises from the inefficiency of water conveyance (Ahmad, 2008a).

An agreement was reached in March 1991 between the provinces on the apportionment of the Indus water to replace a much older agreement. The new agreement has released the provincial canal systems from the need to be operating at all times so as to protect or establish future rights. Now that the supplies have been apportioned, including the formula for sharing any surplus river flows, the provincial systems are free to move toward more efficient water use.

Finances

O&M expenditure is collected by levying water charges and/or drainage taxes. In Punjab and Khyber Pakhtunkhwa, water charges are assessed by the Provincial Irrigation Departments (PIDs). In Sindh and Balochistan, they are assessed by the Provincial Revenue Department (PRD). Water and drainage charges are not linked to O&M needs. They are collected in all regions by PRD, and are deemed to be part of provincial revenues. The gap between O&M expenditures and recoveries through water charges is high (44 percent) and increasing. The difficulties faced in cost recovery have resulted in very poor O&M which, together with deliveries at less than the designed levels and illegal diversion, has led to major inequalities in the distribution of water. In reality, water often does not reach the tail-end users, which can partly explain the increasing groundwater extraction.

The FOs are responsible for collecting the water fee. They retain 40 percent for O&M at the distributary canal level and deposit 60 percent with the AWB for upstream O&M.

The IBIS is the largest infrastructural enterprise accounting for about US$300 000 million investment (at current rates).

Policies and legislation

Since 2005, the Draft National Water Policy is still in the process of being approved. The Pakistan Water Strategy was prepared during 2001, which is the basic document for water development and management. Further, there is no formal Agriculture Policy; although policy decisions have been made on a case-by-case basis. The only approved Integrated Water Resources Management Policy is for Balochistan province.

The 1967 Land Reform Act established a register of rights, which is a cadastral register for land and water rights.

ENVIRONMENT AND HEALTH

Water quality of the Indus river and its tributaries is excellent. Total dissolved solids (TDS) range between 60-374 ppm (parts per million), which is safe for multiple uses (Bhutta, 1999; PWP, 2000). TDS in the upper reaches range between 60 ppm during high-flow to about 200 ppm during low-flow. Water quality deteriorates downstream but remains well within permissible limits, with TDS in the lower reaches of the Indus (at Kotri Barrage) ranging from 150 to 374 ppm. TDS of some of the tributaries such as Gomal River at Khajuri, Touchi River at Tangi Post and Zhob River at Sharik Weir range between 400 to 1 250 ppm (IWASRI, 1997). The quality of the groundwater is marginal to brackish in 60 percent of the IBIS aquifer. The groundwater quality in the area outside the IBIS varyies, depending on recharge (Ahmad, 2008a; Ahmad, 2008b).

Indiscriminate and unplanned disposal of effluents, including agricultural drainage water, municipal and industrial wastewater, into rivers, canals and drains is causing deterioration of water quality downstream. In 1995 around 12.435 km^3/year (9 000 million gallons/day - 1 gallon = 4.5 litres) of untreated water were being discharged into water bodies (Ahmad, 2008b). It was estimated that 0.484 and 0.345 km^3/year (350 and 250 million gallons/day) of sewage was produced in Karachi and Lahore metropolitan areas and most of it was discharged untreated into water bodies. The polluted water is also being used for drinking in downstream areas causing numerous water-borne diseases.

Quality of groundwater varies widely, ranging from < 1 000 ppm to > 3 000 ppm. Around 5.75 million ha have underlying groundwater affected by salinity < 1 000 ppm, 1.84 million ha with salinity ranging from 1 000 to 3 000 ppm and 4.28 million ha with salinity > 3 000 ppm. In addition to TDS, water quality concerns are related to the sodium adsorption ratio (SAR) and residual sodium carbonate (RSC) (WAPADA 2006).

Use of pesticides and nitrogenous fertilizers seriously affects shallow groundwater and entry of effluents into rivers and canals is deteriorating the quality of freshwater. Almost all shallow freshwater is polluted with agricultural pollutants and sewage (Ahmad, 2008a; Ahmad, 2008b).

Investments in drainage have been significant during the last two decades, though waterlogging still affects large tracts of land. Soil salinity and sodicity also constrain farmers and affect agricultural production. These problems are further exacerbated by the use of poor quality groundwater (Kijne and Kuper, 1995). In fresh groundwater areas, excessive pumping by tubewells leads to mining and redistribution of groundwater quality (WRRI, MONA and IIMI, 1999).

Waterlogging in the IBIS has been high in the 1990s because of heavy floods. Early in the 2000s, droughts resulted in lowering of the water table and in reduction of the waterlogged area. The overall analysis shows that there is no change in waterlogging. Currently, waterlogged and saline areas are around 7 million ha. During the late 1990s most of the SCARP tubewells were abandoned and farmers were provided support to install shallow tubewells (Zaman and Ahmad, 2009)

Climate change is also expected to significantly affect agriculture. Potential impacts include vulnerability of crops to heat stress, possible shifts in spatial boundaries of crops, changes in productivity potentials, changes in water availability and use, and changes in land-use systems. Even a fractional rise in temperature could have serious adverse effects, such as considerable increase in growing degree days (GDD, which is a measure of heat accumulation used to predict the date that a flower will bloom or a crop will reach maturity). This could not only affect the growth, maturity and productivity of crops, but would also require additional irrigation water to compensate the heat stress (Afzal, 1997).

The quality of shallow and deep groundwater can adversely impact human and animal health. Around 25 percent of all illnesses diagnosed at public hospitals and dispensaries are gastro-enteric and 40 percent of all deaths, 60 percent of infants' deaths are related to infections and parasitic diseases, most are water-borne. The most common diseases are diarrhoea, dysentery, typhoid, hepatitis, kidney stones, skin disease and malaria.

HIV is not currently a dominant epidemic in Pakistan; however, the number of cases is growing. The World Health Organization (WHO) estimates indicated that the number of HIV/AIDS cases were around 97 000 ranging from the lowest estimate of 69 000 to the highest estimate of 150 000. The overall prevalence of HIV infection in adults aged 15 to 49 is 0.1 percent. The majority of cases go unreported because of social taboos about sex and victims' fears of discrimination. On the other hand, over 900 individuals receive free HIV medicines and tests from nine public and three private sector facilities (WHO, UNAIDS and UNICEF, 2008).

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

The prospects for agricultural water management are:

- Empowerment of users' institutions with an extended role in O&M of irrigation and drainage schemes and improvement of water productivity and access to market and input services.
- Improvement of adequacy, reliability and efficiency of irrigation through improved performance of the public- and private-sector schemes that will result in sustainable irrigated agriculture with safe disposal of effluents to freshwater streams.
- Improvement of farm water productivity with efficient use of water, using higher efficiency irrigation systems, such as furrow irrigation instead of basin irrigation, localized and sprinkler irrigation and control environment agriculture.
- Investments for small-scale irrigated agriculture schemes to generate new livelihoods for the deprived and poor especially in conflict areas bordering Afghanistan.
- Formulation of water and agriculture policies, especially focusing on the policy of Water for Agriculture with the objective of extending the role of agricultural institutions, users' institutions and the private sector in provision of services to farmers.
- Country Assistance Strategies developed by donor agencies (World Bank and ADB) enhanced investments in the water and agriculture sectors. The current involvement of USAID will improve the livelihoods of farmers and the rural poor.

The population is increasing and he agriculture sector must grow at a rate of over 4 percent per year. This target will be achieved with improved performance of existing irrigation schemes and enhanced productivity. This is because new water resources are more difficult to access; the development of large dams, will require at least 10 years before they can be completed. Future growth in agriculture will directly impact groundwater and surface water streams, owing to expanded use of chemicals. As people's diet changes and they increase their consumption of dairy products, meat, fruits and vegetables, the sector will face new challenges for water use. Policy support is required to covert agriculture into a profit-oriented enterprise.

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