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Country profile – Bangladesh

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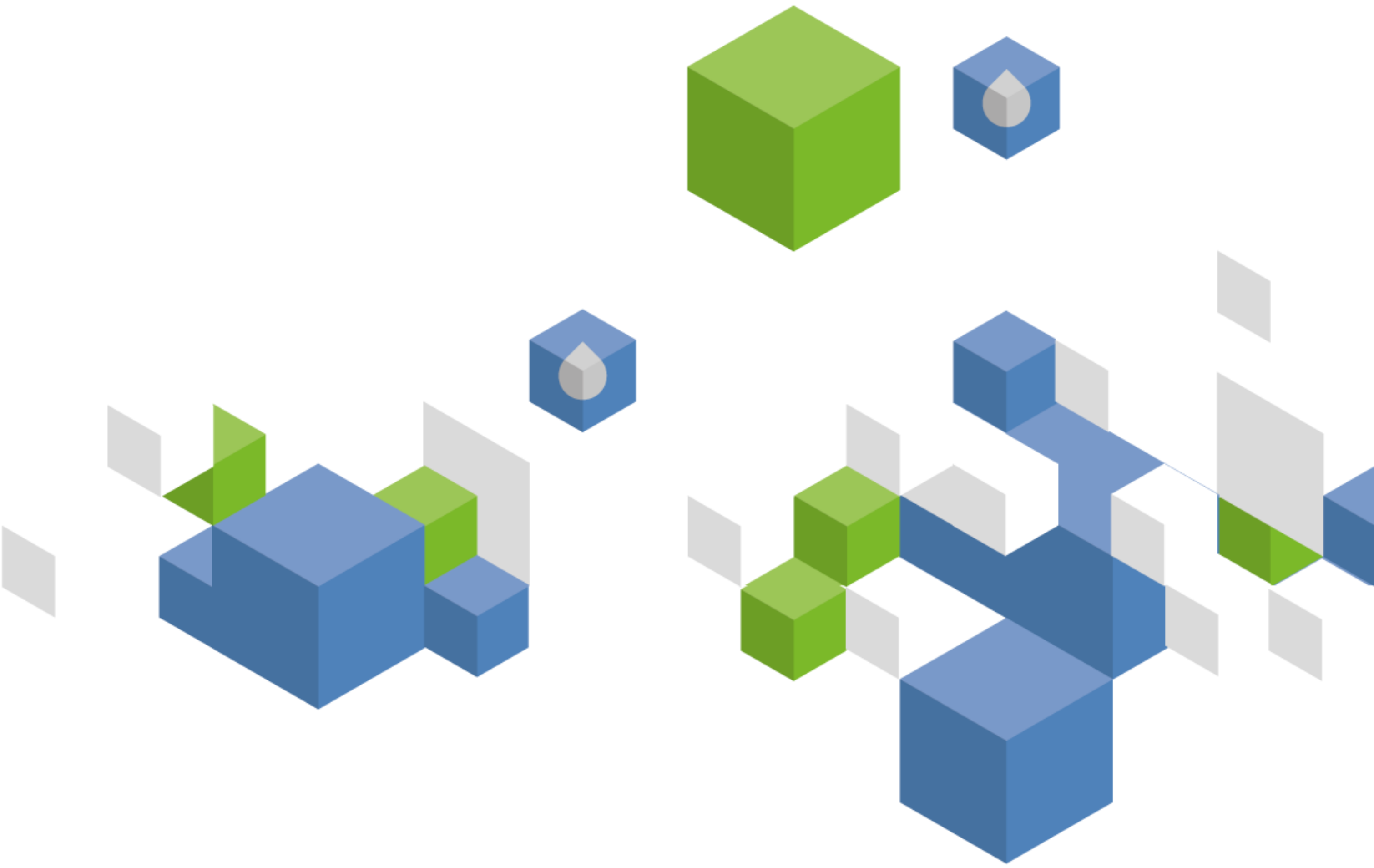

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Bangladesh

GEOGRAPHY, CLIMATE AND POPULATION

Geography

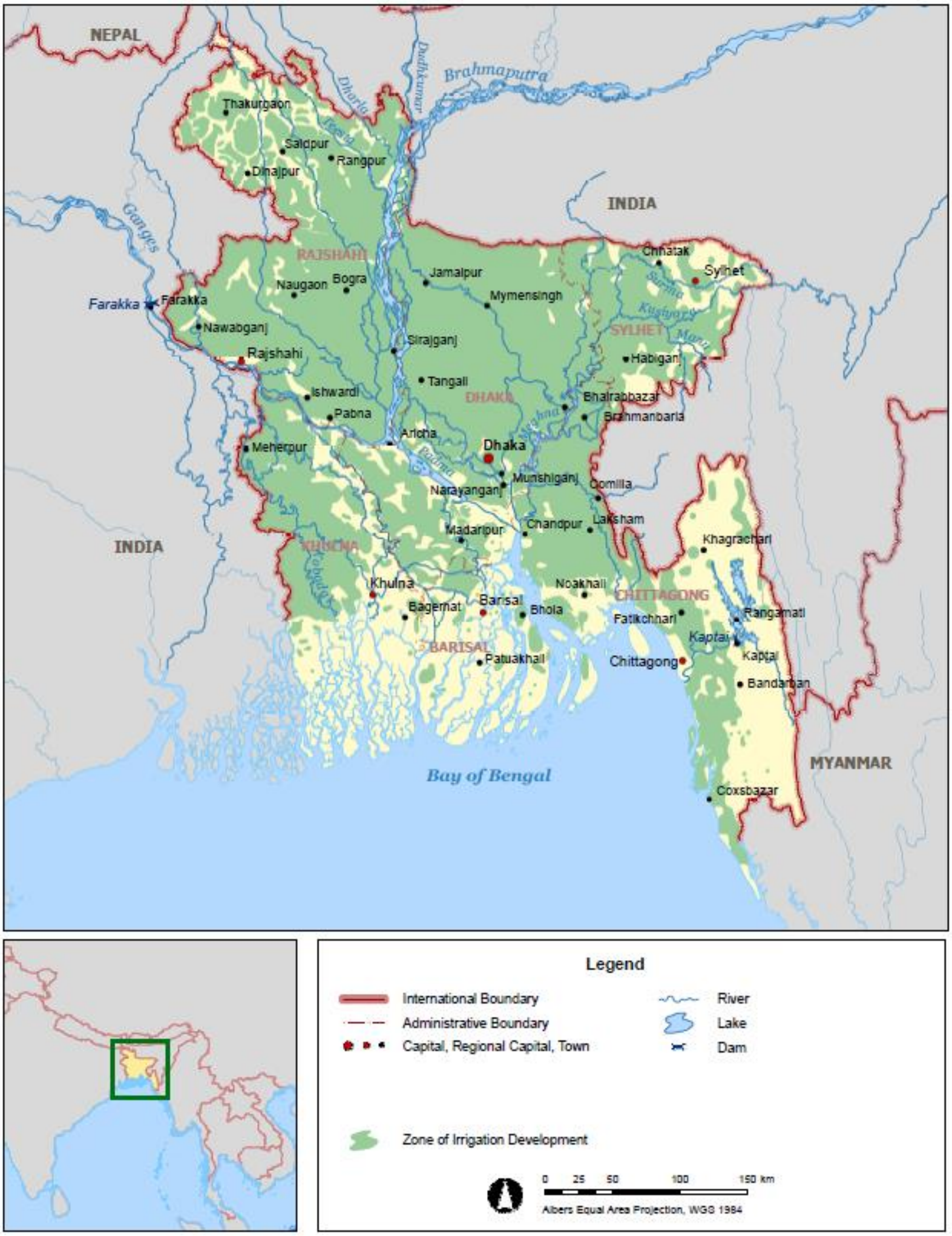
Bangladesh is a low-lying riverine country located in southern Asia, covering 144 000 km^2 (Table 1). The country has been formed as the largest deltaic plain at the confluence of the Ganges, the Brahmaputra (Jamuna) and the Meghna rivers and their tributaries. It has a common border to the west, north and east with India, a short border with Myanmar in the southeast, and is bounded by the Bay of Bengal in the south.

TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2009	14 400 000	ha
Cultivated area (arable land and area under permanent crops)	2009	8 549 000	ha
• as % of the total area of the country	2009	60	%
• arable land (annual crops + temp fallow + temp meadows)	2009	7 569 000	ha
• area under permanent crops	2009	980 000	ha
Population			
Total population	2009	147 030 000	inhabitants
• of which rural	2009	72	%
Population density	2009	1 021	inhabitants/km^2
Economically active population	2009	69 585 000	inhabitants
• as % of total population	2009	47	%
• female	2009	40	%
• male	2009	60	%
Population economically active in agriculture	2009	32 220 000	inhabitants
• as % of total economically active population	2009	46	%
• female	2009	50	%
• male	2009	50	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2009	89 360	million US$/yr
• value added in agriculture (% of GDP)	2009	19	%
• GDP per capita	2009	608	US$/yr
Human Development Index (highest = 1)	2010	0.469	
Access to improved drinking water sources			
Total population	2008	80	%
Urban population	2008	85	%
Rural population	2008	78	%

The country is divided into six administrative divisions, which are named after their respective divisional headquarters: Dhaka, Rajshahi, Chittagong, Khulna, Barisal and Sylhet. The Divisions are subdivided into 64 districts (Zilas) and each district is further subdivided into Upazilas or Thanas, of which there are 508. Finally, each Thana is again subdivided into Unions or Wards, of which there are 6 766.

FIGURE 1
Map of Bangladesh



BANGLADESH

FAO - AQUASTAT, 2011

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About 80 percent of the landmass is made up of fertile alluvial lowland that becomes a part of the Greater Bengal Plain (Lower Gangetic Plain). The country is flat with some hills in the northeast and southeast. A great plain lies almost at sea level along the southern part of the country and rises gradually towards the north. The land elevation on the plain varies from 0 to 90 m above sea level (asl). The maximum elevation is 1 230 m asl at Keocradang in the Rangamati hill district. The geomorphology is comprised of almost 80 percent floodplains some terraces and hilly areas. About 7 percent of the total area of Bangladesh is covered with rivers and inland water bodies and these areas are routinely flooded during the monsoon. Forests cover about 16 percent of the total area of the country.

The total cultivable area is an estimated 8.77 million ha. In 2009, the total cultivated area was an estimated 8.55 million ha, of which 7.57 million ha was for annual crops and 0.98 million ha for permanent crops. Most farmers own less than 1 ha of land and many have less than 0.2 ha.

Climate

Bangladesh has a tropical monsoon climate with significant variations in rainfall and temperature throughout the country. There are four main seasons: the pre-monsoon (March-May), which has the highest temperatures and experiences the maximum intensity of cyclonic storms, especially in May; the monsoon (June-September), when the bulk of rainfall occurs; the post-monsoon (October-November) which, like the pre-monsoon season, is marked by tropical cyclones on the coast; and the cool and sunny dry season (December-February).

About 80 percent of the total rainfall occurs during the monsoon, and the average annual precipitation is 2 320 mm. This varies from 1 110 mm in the extreme northwest to 5 690 mm in the northeast. The country is regularly subjected to drought, floods and cyclones. The country’s mean annual lake evaporation is approximately 1 040 mm, which is about 45 percent of the mean annual rainfall.

Mean annual temperature is about 25°C, with extremes as low as 4°C and as high as 43°C. Ground frost can occur in the hills. Humidity ranges between 60 percent in the dry season and 98 percent during the monsoon.

Population

The total population in 2009 was 147 million, around 72 percent of which lived in rural areas (Table 1). Bangladesh is one of the most densely populated countries in the world with 1 021 inhabitants/km^2. Over the years, the country has succeeded in significantly reducing the population growth rate. In 1991 the population growth rate was 2.17 percent, it is currently 1.39 percent (BBS, 2008). Despite the steadily declining fertility rate, the country’s population is expected to exceed 176 million by 2025, when the population density will rise to about 1 200 persons/km^2.

In 2008, access to improved drinking water sources was 80 percent (85 and 78 percent for the urban and rural population respectively).

ECONOMY, AGRICULTURE AND FOOD SECURITY

In 2009, the total population that was economically active in agriculture was an estimated 32.22 million, amounting to 46 percent of the economically active population, of which 50 percent were women. In 2009, GDP was US$89 360 million of which agriculture accounted for 19 percent.

Despite continuous domestic and international efforts to improve economic and demographic prospects, Bangladesh remains a developing nation. Since 1990 the country has been able to achieve a growth rate of only 5 percent owing to frequent natural disasters (such as cyclones, floods, droughts) and inefficient management of government economic policies and private sector organizations. The Government is currently focussing on agriculture and rural development, power and energy, small and medium enterprises (SMEs), human resource development, creation of employment opportunities, and increasing investment for pro-poor development activities, with a view to achieve macro-economic stability by enhancing the annual GDP growth rate.

Agriculture plays a dominant role in the growth and stability of the economy. The country has a favourable natural environment for crop production. Of the arable land, 33.3 percent is under single cropping, 45 percent double cropping, 11.5 percent triple cropping and 10.2 percent is cultivable waste and currently fallow land. Agriculture is also the prime source of raw materials for most industries.

The agriculture sector comprises crops, livestock, fisheries, homesteads and forestry. Within the crop subsector food grains, particularly rice, dominate for both cropped area and production. Yield of non-cereal crops such as pulses, oil seeds and vegetables including potatoes has almost stagnated, while that of wheat has barely increased.

Bangladesh made steady progress in crop agriculture during the post liberation period. Growth in the agricultural sector averaged over 3 percent/year during the 1970s and the early 1980s. Thereafter, the average growth rate declined to about 1.7 percent, which resulted from the slowdown in irrigation development, the unprecedented flood damage of 1987 and 1988 and the Government cutback in development expenditures for agriculture. Despite the sluggish growth rate in the agriculture sector, food grain production increased at an annual rate of 3 percent during the early 1990s. Much of the increase in production came from irrigated Boro rice.

The cropping intensity increased from 148 percent to 180 percent and food grain production almost doubled from 1970 to 1993. During 2000-2001, total rice production was 25.08 million tonnes. Since then, food grain production, particularly rice crop production, has increased steadily; though it depends on the vagaries of nature. Total rice production during 2007-2008 was 31.67 million tonnes (DAE, 2009) and wheat production in the same year was 0.74 million tonnes (BBS, 2008). Such achievements were possible owing to government efforts to introduce high-yielding varieties (HYV), small-scale irrigation, modern inputs such as fertilizers and pesticides and the use of agricultural machinery.

Despite the growth in food production and its availability, food insecurity is still a major problem because of the lack of purchasing power and therefore access to food, especially for the ultra poor. A major portion of the rural population is landless and, as labourers, they depend on casual earnings for their livelihood. As a result of the seasonal variation in agricultural employment, and limited employment opportunities in the non-farm sector, millions of people suffer from chronic and transitory food insecurity. For this reason, national level food grain availability does not mean household food security. In spite of the increased food grain production and a reduction of the real price of rice, over half of the country’s population cannot afford an adequate diet. The Government has identified food security as an important factor contributing to its socio-economic stabilization and development (MoF and DM, 2006).

WATER RESOURCES

Most of Bangladesh is located within the floodplains of three great rivers: the Ganges, Brahmaputra and Meghna (GBM), and their tributaries, such as the Teesta, Dharla, Dudhkumar, Surma and Kushiyara. The three major river systems drain into the Bay of Bengal through Bangladesh:

- The Brahmaputra river enters Bangladesh from the north and flows south for 270 km to join the Ganges river at Aricha, about 70 km west of Dhaka in central Bangladesh.
- The Ganges river flows east-southeast for 212 km from the Indian border to its confluence with the Brahmaputra, then as the Padma river for about a further 100 km to its confluence with the Meghna river at Chandpur.

- The Meghna river flows southwest, draining eastern Bangladesh and the hills of Assam, Tripura and Meghalay of India to join the Padma river at Chandpur. The Meghna then flows south for 160 km and discharges into the Bay of Bengal.

The combined discharge of the three main rivers is among the highest in the world. Peak discharges are 100 000 m^3/s in the Brahmaputra, 75 000 m^3/s in the Ganges, 20 000 m^3/s in the upper Meghna and 160 000 m^3/s in the lower Meghna.

There are 230 rivers criss-crossing the country, most of which are either tributaries or distributaries to the GBM river systems. The total length of the rivers is approximately 24 000 km and the total GBM catchment area is about 1.75 million km^2, out of which only 7 percent lies within Bangladesh. There are 57 transboundary rivers, of which 54 are shared with India and the remaining three originate in Myanmar.

On average, 1 121.6 km^3 of water crosses the borders of Bangladesh annually, of which 85 percent between June and October. Around 48 percent (537.2 km^3) is contributed by the Brahmaputra, 47 percent (525.0 km^3) by the Ganges, 4 percent (48.4 km^3) by the Meghna/Barak and nearly 1 percent (11 km^3) by other minor rivers to Chittagong in the southeast.

Because of the great disparity between the monsoon floods and the low flow during the dry season, the manageable surface water resources are considered to be 80 percent of the dependable flow in March. Surface water resources are used extensively for dry season irrigation, mainly Boro rice using low-lift pumps (LLPs) and traditional devices.

The availability of groundwater resources in Bangladesh is determined by the properties of the groundwater storage reservoir and the volume of annual recharge. Key factors that determine groundwater availability include the capacity of the country's aquifers to store water, and the characteristics that govern economic withdrawal of groundwater for irrigation, domestic and industrial needs. The source of recharge is rainfall, flooding, and stream flow in rivers. The quaternary alluvium of Bangladesh comprises a huge aquifer with reasonably good transmission and storage properties. Heavy rainfall and inundation during the monsoon substantially recharge aquifers annually.

A regional groundwater recharge assessment took place in 1987 by Master Plan Organization (MPO) under the National Water Plan (NWP) of the Ministry of Water Resources. Subsequently, MPO updated the groundwater resources assessment during the NWP Phase–II in 1991 and the average annual available groundwater recharge for the country was estimated as 21 km^3 (Table 2).

TABLE 2
Regional estimates of annual groundwater recharge (National Water Plan) (Source: MPO, 1987 and 1991)

Region	Area (million ha)	Usable recharge (million m^3)		Available recharge (million m^3)	
		NWP-I	NWP-II	NWP-I	NWP-II
Northwest – NW	3.016	13 400	12 100	9 480	9 786
Northeast – NE	3.569	17 800	23 100	9 615	9 594
Southeast – SE	3.007	9 000	9 800	1 538	1 498
South Central – SC	1.426	3 600	3 500	1 801	1 249
Southwest – SW	2.562	3 900	5 600	1 980	1 961
Total	**13.580**	**47 700**	**54 100**	**24 414**	**21 088**

The internal renewable water resources are an estimated 105 km^3/year (Table 3). The overlap is considered negligible, this includes 84 km^3 of surface water produced internally as stream flows from rainfall and about 21 km^3 of groundwater resources produced within the country. Part of the groundwater comes from the infiltration of surface water with an external origin. Since annual cross-border river flows and entering groundwater are estimated to be 1 121.6 km^3, the total renewable water resources are therefore estimated to be 1 226.6 km^3.

TABLE 3
Water resources

Renewable freshwater resources			
Precipitation (long-term average)	-	2 320	mm/yr
	-	334 000	million m^3/yr
Internal renewable water resources (long-term average)	-	105 000	million m^3/yr
Total actual renewable water resources	-	1 226 600	million m^3/yr
Dependency ratio	-	91.4	%
Total actual renewable water resources per inhabitant	2009	8 343	m^3/yr
Total dam capacity	2013	6 477	million m^3

The Kaptai dam on the Karnafuli river in Rangamati Hill district in the Chittagong Hill Tracts is the only large dam constructed in Bangladesh, mainly for hydro-electric power purposes. Its total capacity is 6.477 km^3. In addition, there are barrages constructed across the Teesta, Tangon and Manu rivers, which are used as diversion structures for irrigation only.

In 1995, the installed capacity of all the country's power plants was about 2 907 MW, of which about 230 MW was hydroelectric.

INTERNATIONAL WATER ISSUES

India controls the flow of the Ganges river with a dam completed in 1974 at Farraka, 18 km from the border with Bangladesh. This dam was a source of tension between the two countries, when Bangladesh asserted that the dam held back too much water during the dry season and released too much water during monsoon rains. A treaty was signed in December 1996 under which Bangladesh is ensured a fair share of the flow reaching the dam during the dry season. Such agreements for other transboundary rivers are yet to be made for equitable share of surface water resources of the country.

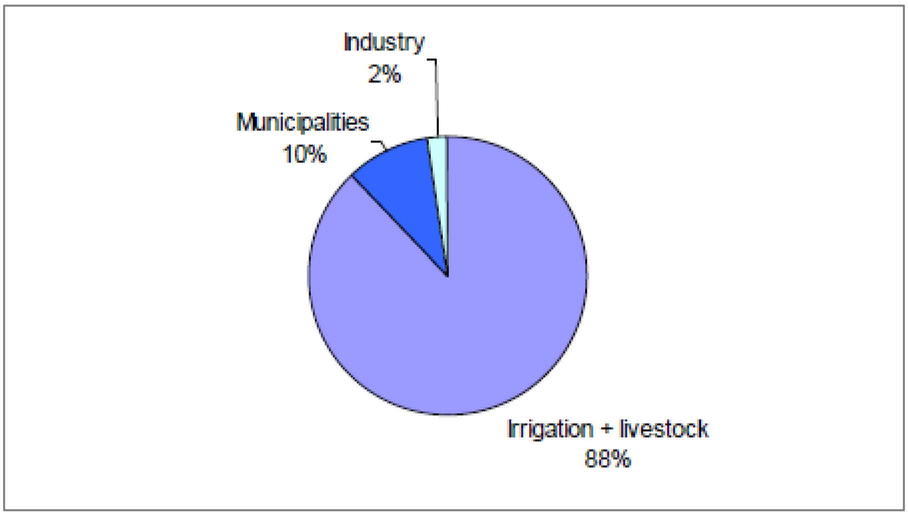
WATER USE

In 2008, the total water withdrawal was an estimated 35.87 km^3, of which 31.50 km^3 (88 percent) was for agriculture, 3.60 km^3 (10 percent) for municipalities and 0.77 km^3 (2 percent) for industries (Table 4 and Figure 2).

TABLE 4
Water use

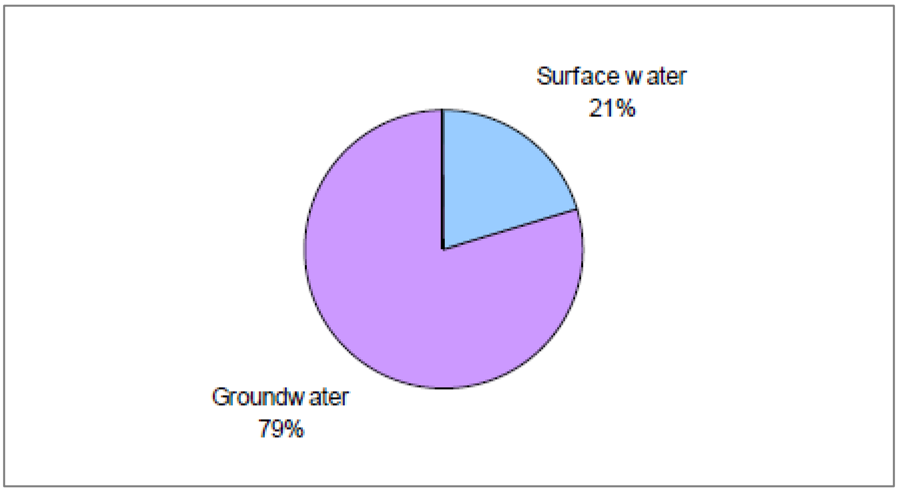
Water withdrawal			
Total water withdrawal	2008	35 870	million m^3/yr
- irrigation + livestock	2008	31 500	million m^3/yr
- municipalities	2008	3 600	million m^3/yr
- industry	2008	770	million m^3/yr
• per inhabitant	2008	247	m^3/yr
Surface water and groundwater withdrawal	2008	35 870	million m^3/yr
• as % of total actual renewable water resources	2008	2.9	%
Non-conventional sources of water			
Produced wastewater		-	million m^3/yr
Treated wastewater		-	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

FIGURE 2
Water withdrawal by sector
Total 35.87 km^3 in 2008



Approximately 28.48 km^3, or 79 percent of the total water withdrawal, comes from groundwater and 7.39 km^3, or 21 percent, from surface water (Figure 3).

FIGURE 3
Water withdrawal by source
Total 35.87 km^3 in 2008



IRRIGATION AND DRAINAGE

Evolution of irrigation development

Irrigation is considered to be a necessary precondition for the enhancement of agricultural production. The earliest approach to irrigation facilities was during 1960-1970 with the construction of large-scale multipurpose irrigation, flood control and drainage projects. To some extent, these projects were successful for flood control and protecting coastal areas from tidal bores and saltwater intrusion. But they played a minor role in irrigation development and only about 7 percent of the total irrigable area was covered by these very costly projects. Though the country has abundant surface water resources, particularly in the monsoon season, its flat deltaic topography and the instability of major rivers make large gravity irrigation systems both technically difficult and costly. On the other hand, during the dry season irrigation using surface water has become difficult or practically impossible owing to the limited availability of surface water. Therefore the use of groundwater for irrigation has become increasingly important.

The expansion of minor (small-scale) irrigation is a vital component of the Government's agriculture strategy. Minor irrigation consists of low lift pumps (LLP: power operated centrifugal pumps drawing water from rivers, creeks and ponds), shallow tubewells (STW: with a motorized suction mode pumping unit), deep tubewells (DTW: with a power operated force mode pumping unit), manually operated pumps (MOP: extracting water from a shallow tubewell) and traditional systems. At the end of the dry season, the water level falls beyond the suction limit of the centrifugal pump. In these situations, it is possible to draw water by placing the STW in a pit, which is called a deep-set shallow tubewell (DSSTW) or a very deep-set shallow tubewell (VDSSTW). Where static water levels fall further (over 10.7 m), a submersible or vertical turbine (FMTW: force mode tubewell) is needed.

Between 1950 and 1987, public tubewells, regulations governing private installations and public monopolies of the supply of pumps, motors and other equipment constrained irrigation development. Since 1972, the emphasis has been on minor irrigation using low lift pumps and tubewells (STW, DTW and FMTW).

From 1979 to 1984, there was a liberalized expansion of minor irrigation, mainly with STW in the private sector. In 1982, about 1.5 million ha were under food crop irrigation. The rate of minor irrigation development slowed from 39 000 STW in 1984 to less than 5 000 in 1986. This was because of a number of reasons: private sector STW sales were limited, there was official concern over reported declines in groundwater levels where STW operated, an embargo on all diesel engines was imposed in 1985, and engines were standardized.

In 1991, the National Minor Irrigation Development Project (NMIDP) was established in response to the needs of farmers and the requirement for increased private sector investment in minor irrigation technologies. The project activity mainly concentrated on VDSSTW and FMTW technology, whereas irrigation using STW was mainly controlled by the private sector. In 1994, 665 VDSSTW and 32 FMTW had been constructed by farmers as a result of the promotional action of the project. However, there has been a general reduction in the area irrigated by wells because of aquifer drawdown, and there has been an increase in salinity intrusion particularly along the coastal areas in the southwest of the country.

Currently, the irrigation potential is estimated as 6.93 million ha. During 2006, there were 29 170 DTW, 1 202 720 STW and 107 290 LLP and the total irrigated area was an estimated 4.88 million ha; where groundwater and surface water coverage were 81 percent and 19 percent, respectively. In 2008 the national irrigation coverage was 5.05 million ha, where groundwater covered 79 percent and surface water covered 21 percent of the total irrigated area (Figure 4 and Table 5). Table 6 gives a summary of irrigation methods using surface water and groundwater during 2008 is presented in Table 5.

FIGURE 4
Source of irrigation water on area equipped for full control irrigation
Total 5 049 785 ha in 2008

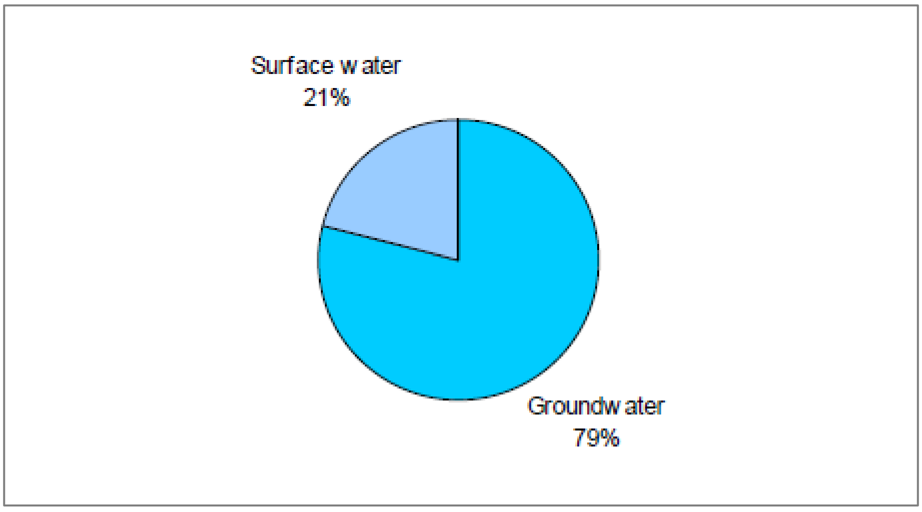


TABLE 5
Irrigation and drainage

Irrigation potential			6 933 000	ha
Irrigation				
1. Full control irrigation: equipped area		2008	5 049 785	ha
- surface irrigation		2008	5 049 785	ha
- sprinkler irrigation		2008	0	ha
- localized irrigation		2008	0	ha
• % of area irrigated from surface water		2008	21	%
• % of area irrigated from groundwater		2008	79	%
• % of area irrigated from mixed surface water and groundwater			-	%
• % of area irrigated from mixed non-conventional sources of water			-	%
• area equipped for full control irrigation actually irrigated		2008	5 049 785	ha
- as % of full control area equipped		2008	100	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)			-	ha
3. Spate irrigation			-	ha
Total area equipped for irrigation (1+2+3)		**2008**	**5 049 785**	**ha**
• as % of cultivated area		2008	60	%
• % of total area equipped for irrigation actually irrigated		2008	100	%
• average increase per year over the last 13 years		1995-2008	2.3	%
• power irrigated area as % of total area equipped		2008	97	%
4. Non-equipped cultivated wetlands and inland valley bottoms		1993	1 545 000	ha
5. Non-equipped flood recession cropping area			-	ha
Total water-managed area (1+2+3+4+5)		**2008**	**6 594 785**	**ha**
• as % of cultivated area		2008	79	%
Full control irrigation schemes	**Criteria**			
Small-scale schemes	< ha	2008	4 910 982	ha
Medium-scale schemes				ha
large-scale schemes	> ha	2008	138 803	ha
Total number of households in irrigation			-	
Irrigated crops in full control irrigation schemes				
Total irrigated grain production			-	metric tons
• as % of total grain production			-	%
Harvested crops				
Total harvested irrigated cropped area		2008	5 976 810	ha
• Annual crops: total		2008	5 936 810	ha
- Wheat		2008	313 000	ha
- Rice		2008	4 341 000	ha
- Maize		2008	90 000	ha
- Millet		2008	400	ha
- Sorghum		2008	100	ha
- Barley		2008	810	ha
- Other cereals		2008	25 000	ha
- Potatoes		2008	263 000	ha
- Pulses		2008	156 000	ha
- Vegetables		2008	236 000	ha
- Cotton		2008	6 500	ha
- Tobacco		2008	18 000	ha
- Sesame		2008	30 000	ha
- Sugarcane		2008	43 000	ha
- Other annual crops		2008	414 000	ha
• Permanent crops: total		2008	40 000	ha
- Tea		2008	40 000	ha
Irrigated cropping intensity (on full control actually irrigated area)		2008	118	%
Drainage - Environment				
Total drained area		1993	1 501 400	ha
- part of the area equipped for irrigation drained		1993	118 400	ha
- other drained area (non-irrigated)		1993	1 383 000	ha
• drained area as % of cultivated area		1993	17	%
Flood-protected areas			-	ha
Area salinized by irrigation		1993	100 000	ha

TABLE 6
Irrigation using surface water and groundwater by different modes (2008) (Source: MoA, 2008)

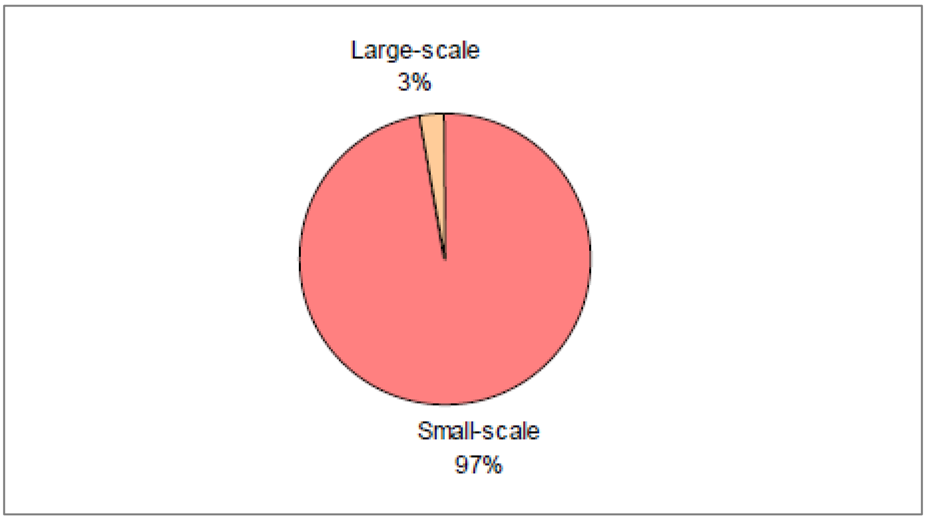
	Mode of Irrigation	Number of equipment	Area irrigated (ha)	as % of total irrigated area	Area irrigated (ha) per equipment
A.	**Irrigation through utilization of surface water**				
1	Low-lift pump	138 630	903 867	17.90	6.52
2	Gravity flow		138 803	2.75	
3	Traditional method		19 044	0.38	
	Sub-total	**138 630**	**1 061 714**	**21.02**	
B.	**Irrigation through utilization of groundwater**				
1	Deep tubewell	31 302	785 680	15.56	25.10
2	Shallow tubewell	1 304 973	3 197 184	63.31	2.45
3	Manual and artesian wells		5 207	0.10	
	Sub-total	**1 336 275**	**3 988 071**	**78.98**	
	Grand total	**1 474 905**	**5 049 785**	**100.00**	

In 1993, the total area of wetlands was 3.14 million ha, of which almost 1.55 million ha were cultivated. Thus, total water managed area is an estimated 6.59 million ha.

Surface irrigation is the only technology used in large irrigation schemes. In 2008, the total area equipped for full control irrigation covered by large irrigation schemes (major irrigation) was an estimated 0.14 million ha (3 percent). Small irrigation schemes covered a total area of 4.91 million ha (97 percent) (Figure 5).

In 1992, the average cost of irrigation development for large surface water schemes operated by the Bangladesh Water Development Board (BWDB) was an estimated US$ 522/ha as reported by the Food and Agriculture Organization of the United Nations (FAO, 2007). At that time the operation and maintenance (O&M) costs of these projects was estimated at US$ 100/ha; but under the 1983 Irrigation Ordinance, BWDB collected only Tk250/ha (nearly US$ 6/ha) as O&M fees. The average cost of irrigation development in minor irrigation schemes including O&M was estimated at US$ 50/ha in 1990-1991; recently this has risen to US$ 113/ha (BBS, 2008).

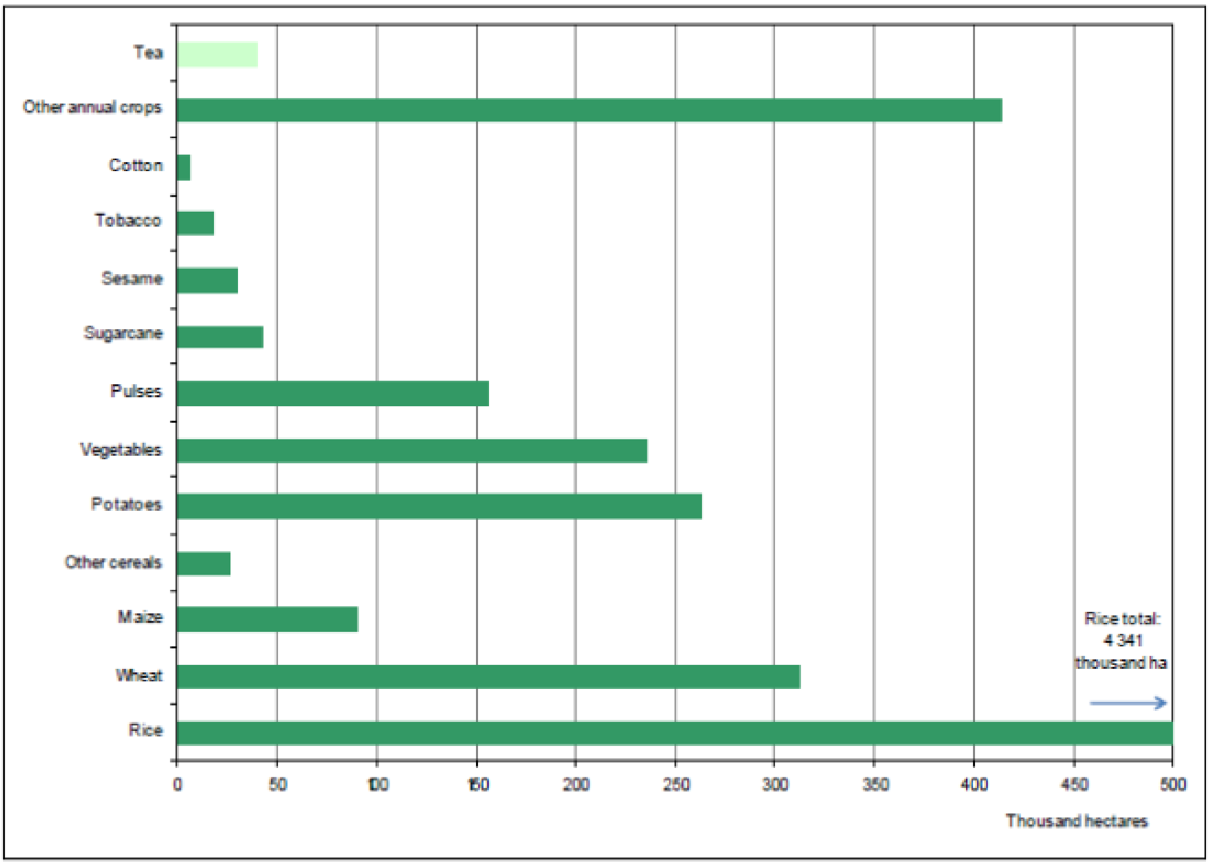
FIGURE 5
Type of full control irrigation schemes
Total 5 049 785 ha in 2008



Role of irrigation in agricultural production, the economy and society

In 2008, total harvested irrigated cropped area was estimated at 5.98 million ha, of which the most important crops are rice accounting for 4.34 million ha (73 percent), wheat 0.31 million ha (5 percent), potatoes 0.26 million ha (4 percent) and vegetables 0.24 million ha (4 percent) (Table 5 and Figure 6).

FIGURE 6
Irrigated crops on area equipped for full control irrigation
Total harvested area 5 976 810 ha in 2008 (cropping intensity on full/control equipped area: 118.3 %)



Improved irrigation water management (IWM) practices, increased use of modern variety (MV) seeds and fertilizers have made a major break through in achieving almost self-sufficiency for cereal crop production. Irrigation is mainly practiced in the dry season to cultivate Boro rice and wheat. Supplementary irrigation could appreciably increase transplanted Aman rice production by mitigating the effects of drought.

Irrigated paddy yield is moderately high, ranging from 3.85 to 4.75 tonnes/ha. During 2007-2008 total Boro rice production (including HYV, hybrid and local varieties) amounted to 18.67 million tonnes and the total rice (Aus, Aman and Boro together) was 31.67 million tonnes (DAE, 2009). The total irrigated rice production was about 58 percent of the country's total rice production.

Status and evolution of drainage systems

Because of the low-lying topography, about 26 500 km^2 or 18 percent of the country is inundated during the monsoon season each year. During severe floods the affected area may exceed 53 000 km^2 or 37 percent of the country and in extreme events, such as in the 1998 flood, about 66 percent of the country is inundated. Floods are caused by overspills from main rivers and their distributaries, overspills from tributaries and by direct rainfall. Flood control works can reduce floods caused by the first two, but only drainage can have any effect on the latter two. The basic benefit of drainage is water control – supply as well as removal. The particular benefits can be: i) potential increase in cropped area with earlier drainage; ii) higher yields from transplanted Aman rice with early planting; iii) crop diversification in the wet season with better drainage; and iv) more control over crop calendars and patterns with control of the water regime.

In 1964, a master plan was developed for water resources development. This envisaged the development of 58 flood protection and drainage projects covering about 5.8 million ha of land. Three types of polders were envisaged: gravity drainage, tidal sluice drainage and pump drainage.

Flood control and drainage projects have accounted for about half of the funds spent on water development projects since 1960. They include:

- large-scale projects such as the Coastal Embankment Project (949 000 ha), the Manu River Project (22 500 ha), the Teesta Right Embankment (39 000 ha), the Ganges-Kobadak Project (141 600 ha), the Brahmaputra Right Flood Embankment (226 000 ha), the Chandpur Irrigation Project (54 000 ha), and the Chalan Beel Project (125 000 ha);
- medium-scale projects such as the Sada-Bagda, Chenchuri Beel and Bamal-Salimpur-Kulabasukhali projects implemented under the Drainage and Flood Control Projects (DFC I to DFC IV) and financed by the World Bank. These projects typically cover areas of 10 000-30 000 ha and involve flood control and drainage with limited irrigation development; and
- small-scale projects such as those implemented under the Early Implemented Project, the Small-scale Irrigation Project and the Small-scale Drainage and Flood Control Project.

During the National Water Plan Phase I and Phase II period (1986-1991) the Master Plan Organization (MPO) made a comprehensive assessment of the ongoing water resources development projects (large-scale irrigation projects, flood control and drainage (FCD) projects, and flood control, drainage and irrigation (FCDI) projects. It was noted that the performance of FCD and FCDI projects needs to be improved under the NWP. The FCD projects under this NWP strategy would focus on gravity drainage schemes in shallow to medium flooded areas, and submersible embankments in deeply flooded areas. After 1991, FCD projects were implemented under the Flood Action Plan (FAP) by the MoWR. This was a comprehensive plan for the progressive reduction of floods from major rivers in association with improved drainage systems. Under the existing Five Year Plan (Planning Commission, 2009), the Government approved 12 FC and FCD investment projects in the Annual Development Programme (ADP) (2009-2010).

In 1993, the total area of wetlands was 3.14 million ha, of which 1.55 million ha were cultivated and 1.38 million ha were drained by surface drains. In 1992, the average cost of drainage development was US$ 192/ha.

Different types of floods occur in Bangladesh. Of the total cropped area, about 1.32 million ha are severely flood-prone and 5.05 million ha are moderately flood-prone. The flood protected area in 1990 was an estimated 4.20 million ha.

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

Institutions

In Bangladesh, public sector involvement in irrigation water management (IWM) is shared between three ministries. Minor irrigation and small-scale surface irrigation schemes are under the jurisdiction of the Ministry of Agriculture (MoA) and the Ministry of Local Government, Rural Development and Cooperatives (LG&RD), respectively. Large-scale irrigation schemes, including FCD projects, are under the Ministry of Water Resources (MoWR).

The MoA is mainly concerned with agricultural policy development, planning and monitoring. Project delivery is the responsibility of its various agencies, the most important being the Bangladesh

Agricultural Development Corporation (BADC). In the past, the BADC was directly involved in supplying inputs to minor irrigation and looked after the O&M of all sorts of equipment. It has now withdrawn from all commercial operations relating to minor irrigation, leaving them to the private sector. The Department of Agriculture Extension (DAE) demonstrates and extends information to farmers on crops, agronomic practices and use of on-farm water management and agricultural machinery. The Barind Multipurpose Development Authority (BMDA), under the MoA is also responsible for water resources management in agricultural development of the Barind Tracts region.

The Local Government Engineering Department (LGED), under the MoLG&RD, implemented Small-Scale Water Resources Development (SSWRD) projects Phase I and II by constructing 26 rubber dams in the medium and small rivers in different parts of the country. LGED was also responsible for participatory management of these projects, which was achieved by forming the Water Management Cooperative Associations (WMCAs) for each project. The Bangladesh Rural Development Academy (RDA), under the MoLG&RD, is currently implementing a package model of Multipurpose Low-Cost DTW Projects in different parts of the country with a view to achieving optimum utilization of water resources for irrigation, domestic and other purposes such as fisheries, livestock rearing and nurseries. These multiple uses bring significant benefits and contributions to livelihoods, especially for poor households.

Under MoWR, the Bangladesh Water Development Board (BWDB) is responsible for the planning, implementation and operation of medium- and large-scale surface water irrigation schemes, FC and FCD projects. The Water Resources Planning Organization (WARPO), under the same ministry, has a mandate to ensure coordination of all relevant ministries through the National Water Council and to plan all aspects of water resources development including large-scale and minor irrigation, navigation, fisheries and domestic water supplies.

Water management

Water Management (WM) is considered to be the planned development, distribution and use of water resources, in accordance with predetermined objectives with respect to both quantity and quality of water. WM deals with integration of all activities having the aim of systematically controlling the inter-relationship between water and society. The the main purpose is to limit damage caused by water and reduce its exploitation both technically and economically. Therefore, WM has become important for addressing increasing pressure on available water resources. Agriculture is the greatest consumer of water resources, accounting for approximately 88 percent of all the freshwater withdrawn (Figure 1). Modern high-yield and diversified crop production systems can be sustained only with the proper utilization of irrigation water and management at the farm level.

Though there has been a significant increase in irrigated agriculture over the last decade, most minor and major irrigation systems have shown poor field performances owing to a lack of technical know-how, as well as poor on-farm water management (OFWM) practices. The Government has recognized the importance of introducing appropriate water management techniques and technologies at farm level as key to ensuring food security, employment generation and eliminating poverty through intensification and diversification of agricultural production. With this view, MoA has undertaken some development projects for improving the efficiency and overall performance of irrigation systems with better OFWM practices. Few investment projects have been initiated by the Government, some have been financed by donor agencies under the Technical Assistance (TA) programme.

Participation of women in IWM activities has not been encouraged; though in many villages they are active in other agricultural practices such as post-harvest processing, home gardening, rearing of livestock and poultry. However, here and there women operate treadle pumps for irrigation. Moreover, indigenous and tribal women are involved in collecting water for domestic purposes and irrigating homestead gardens.

Policies and legislation

There are no policies or acts related to irrigation or water management. This is because of rapid growth during the 1980s of minor irrigation using DTW and STW. In 1985, the MoA enacted the Groundwater Management Ordinance, which controlled the spacing for installation of irrigation equipment. This Ordinance was suspended in 1987 with a view to expansion of minor irrigation (mainly STW irrigation) to the private sector. Because of the suspension of space requirements for irrigation equipment, optimum utilization of groundwater resources has been impeded. In recent years, however, Government policies such as the National Agriculture Policy – NAP (MoA, 1999), National Water Policy – NWPo (MoWR, 1999) and the National Water Management Plan – NWMP (MoWR, 2001) have, to some extent, addressed the minor irrigation and water management issues.

Minor irrigation has been in the domain of private sector agriculture, where there has been a rapid expansion of irrigated agriculture, which resulted in a significant increase in crop production. In this regard, the Government has given special emphasis to minor irrigation development in the NAP, which was formulated in 1999. In relation to irrigation water management the mandate of the NWPo (MoWR, 1999) is to focus on increasing efficiency by recycling drainage water; rotational irrigation; introducing cropping patterns that conserve water; the conjunctive use of both surface water and groundwater; addressing the non-point pollution of water systems by fertilizer and pesticides, and issues of equity and social justice.

The NWMP, which was formed by the MoWR in 2001, has the mandateto address the overall issues of water resources management. It provides direction to short-, medium- and long-term action plans. The NWMP has emphasized the expansion of private STW irrigation in slow-growth regions, and issues are to be addressed that are related to arsenic pollution and salinity; especially in the coastal areas

ENVIRONMENT AND HEALTH

Bangladesh is now widely recognized as one of the countries that is most vulnerable to climate change. Increased variability of temperatures and rainfall and increased occurrence of natural hazards are expected to affect the availability of both surface water and groundwater. Investment is required to ensure a continuous and sustainable access to water resources.

As a result of the limited availability of surface water during the dry season, the use of groundwater has become increasingly important as a source of water for irrigation, municipal and industrial purposes. In many areas environmental hazards have been encountered, and a number of adverse effects have emerged owing to the overexploitation of groundwater, such as lowering of water tables, reduction in dry season flows of rivers and streams, groundwater pollution, intrusion of saline water in coastal areas, ecological imbalance and possible land subsidence. There is evidence of permanent depletion of groundwater levels in some locations, particularly in the Dhaka metropolitan area, where the water level’s average annual decline is about 3 m (BADC, 2006), and in the northwest region of the country.

In 1993, the estimated area affected by salinity caused by by irrigation was 100 000 ha.

Irrigation water quality has deteriorated in some locations because of pollution caused by agrochemicals, industrial waste and other sources. Arsenic contamination of groundwater, particularly water from STW and HTW, in 59 out of 64 districts, has been reported by many government and donor agencies (GoB, UNICEF, WB, FAO). In most regions, maximum arsenic concentration has been found within the upper 50 m depth of aquifers (Water Aid, 2000). In many places, concentration of iron and arsenic in irrigation water has gone beyond the limit of the safe water quality standards of Bangladesh and the World Health Organization (WHO). Some diseases and health hazards such as arsenicosis, blindness, physical disability, occur as a result of arsenic toxicity to human body (RDA, 2001). Throughout the country, about 1.44 million tubewells (STWS and HTWs have been affected by arsenic contamination and about 30 million people are exposed to arsenic toxicity (Ahmed, 2007).

In some parts of the country, particularly the Barind Tracts in the northwest region, there are already symptoms of deterioration in the natural hydrological regime. Declining groundwater levels have affected water quality causing it to affect soils, the growth of agricultural crops, flora and fauna and to increase health hazards. Therefore, careful consideration should be given to these environmental issues in order to harness the beneficial uses of irrigation water comprising both surface water and groundwater resources.

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

Under climate change and the related increased temperatures, evapotranspiration will increase and the river system will suffer during dry months because of the acute low-flow condition. Consequently, the dry season water demand for irrigated agriculture, salinity control, and stream flow maintenance will increase significantly leading to the escalating shortfall in water supplies. Greater cooperation is required between the riparian countries to augment dry season flows in the transboundary rivers so as to meet the increasing gaps in water availability.

The main source of irrigation water during the last decade has been groundwater. There is a question of risky over-dependence, and over use of this water resource, and related quality constraints and emerging environmental concerns. The NWMP (MoWR, 2001), therefore, focuses on short-term and long-term strategies for agricultural water management, such as: i) balanced conjunctive use of surface water and groundwater resources; ii) future growth of tubewell irrigation with FMTWs; iii) surface water conservation and rainwater harvesting using rubber dams in small and medium rivers; iv) new low-cost major irrigation schemes (gravity flow system); and v) larger floating pumps, particularly in the southeastern part of the country.

On-farm water management (OFWM) can be considered as a potentially useful measure to save irrigation water use per hectare and to expand the irrigation command area, mainly for STW and LLP irrigation within the coastal zone and other water crisis areas. Wherever feasible, tubewell irrigation should be integrated with domestic water supply. The RDA developed multipurpose low-cost DTW technology package is one that can be replicated in suitable areas.

According to NWP estimates in 1991, the expansion of irrigation coverage would reach its maximum potential limit by 2025. However, the rate of increase in water demand is expected to decline in response to demand-management practices such as conservation, water-use efficiency, recycling.

The strategy of water resources development has so far been centered on flood control and irrigation expansion to promote food grain production. Without denying the importance of food production and food security, it is now widely recognized that conflicts among alternative and competing uses of water are becoming sharper as the demand for water has been increasing. It is, therefore, necessary to formulate a long-term vision for IWRM to address the demands of all water using sectors in order to sustainably maintain the environment.

Some challenging issues that are related to agricultural water management, such as arsenic pollution, climate change, salinity, have been found in many locations. The impacts of which have already been discussed. As a result of reduced freshwater flows, caused by upstream abstraction of the Ganges water, the salinity front in the coastal areas of Bangladesh has already advanced. About 10 percent of the southwest region has experienced increased salinity in the wet season, which rises to 40 percent in the dry season (BWP, 2000).

The salinity problem adversely affects the availability of required irrigation water in this region. The possible solution to this particular problem could be to take advantage of the Ganges Water Sharing Treaty of 1996 between India and Bangladesh, which specified the amount of water to be released downstream of Farraka during the dry season. A major endeavour, to meet this end, is the Gorai

Restoration Project. Moreover, assured in-stream flows in the Ganges have increased the potential for surface water augmentation in the southwest region after construction of the Ganges Barrage.

MAIN SOURCES OF INFORMATION

Ahmed, M. Feroze. 2007. *Integrated water resources management in Bangladesh.* RSS Workshop on IWRM, Dhaka, Bangladesh. University of Engineering & Technology, .

BADC (Bangladesh Agricultural Development Corporation). 2006. *Groundwater zoning map and its application.* A National Seminar Paper presented by Eftekharul Alam, April 9, Dhaka, Sech Bhaban.

BBS (Bangladesh Bureau of Statistics). 2008. *Statistical Pocket Book of Bangladesh.* Ministry of Planning, GoB.

BWP (Bangladesh Water Partnership). 2000. *Bangladesh Water Vision 2025 – Towards a sustainable water world.* Dhaka, Global Water Partnership/BWP.

DAE (Department of Agricultural Extension). 2009. *Agriculture Diary 2009.* Agricultural Information Service Wing, DAE, Ministry of Agriculture, GoB.

FAO. 2007. *Water Profile of Bangladesh.* Updated Version (June, 2007).

MPO (Master Plan Organization). 1986. *National Water Plan Summary Report.* Ministry of Water Resources, GoB/UNDP.

MPO. 1987. *The groundwater resource and its availability for development.* Technical Report 5, National Water Plan Phase –I, Ministry of Water Resources, GoB.

MPO. 1991. *National Water Plan Phase II.* Vol I & II, Ministry of Water Resources, GoB.

MoA (Ministry of Agriculture). 1999. *National Agriculture Policy (NAP).* GoB.

MoA. 2008. *Minor irrigation survey report 2007-08.* Survey and Monitoring Project, BADC, October, Dhaka.

MoF&DM (Ministry of Food and Disaster Management). 2006. *National workshop on food security.* Dhaka

MoWR (Ministry of Water Resources). 1999. *National Water Policy (NWPo).* GoB.

MoWR. 2001. *National Water Management Plan.* GoB.

Planning Commission. 1998. *The Fifth Five Year Plan, Ministry of Planning.* GoB.

Planning Commission. 2009. *The Annual Development Programme (ADP) 2008-09.* Ministry of Planning, GoB.

RDA (Rural Development Academy). 2001. *Safe drinking water supply through RDA- developed low-cost deep tubewell.* A Report prepared by M.A. Matin, M.H. Khan and M.N.I. Khan, RDA, Bogra, November 2001.

Water Aid. 2000. *An overview of the arsenic issues in Bangladesh.* Edited by M. Jones Elizabeth, Dhaka, Water Aid Bangladesh.

WARPO (Water Resources Planning Organization). 2009. *National water resources database (NWRD).* Ministry of Water Resources, GoB.

United Nations. 2009. *World population prospects (Table-A.1 2008 revision).* Department of Economic and Social Affairs, Population Division.