Journal of Developments in Sustainable Agriculture 2: 35–44 (2007)

Utilization and Conservation of Water Resources in Bangladesh

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Utilization of water resources in Bangladesh depends on their availability and conservation depends on storability subject to upstream conditions of the lower riparian countries. Bangladesh is located at the lower riparian region of the three major internationally famous rivers, namely the Ganges, the Brahmaputra and the Meghna. Management and development of the water resources of the country is completely dependent on the availability of water from the transboundary rivers and annual distribution of rainfall. It has been recognized that Bangladesh experiences water shortages in the dry season and water abundance in the wet season, which significantly disrupt the agro-environmental practices and socio-economic activities of the country. To address the problems encountered due to water shortage or abundance, cooperation among the co-basin countries is needed, as well as proper utilization and conservation of water resources. Agro-environmental education now should focus on these issues with the perspective of Bangladesh as well as the global aspects. This paper describes the problems of water resources management and development, utilization and conservation options based on available data and information in the context of Bangladesh and possible remedial measures to address and overcome the problems.

Key words: water demand, water supply, conservation, utilization, agro-environmental

1. Introduction

In agro-environmental practices, water resources play a key role over other variables. Agricultural activities and most of the environmental issues are related to water. So water availability and its proper utilization is a major concern for sustainable development of agriculture. Agriculture and environment are always interrelated and these two broad areas should be the priority considered in planning and evaluation of any agricultural projects. Water resources management and their proper utilization improve the agro-environmental conditions of a country. Compliance with policies is intended to ensure that the development and management of the nation's water resources include the protection, restoration and preservation of natural habitats and their dependent biodiversity with specific provisions for wetlands, mangroves, other forests, endangered species and water quality. Utilization of water resources in Bangladesh depends on their availability and conservation depends on the storability due to upstream conditions of the lower riparian countries. Water conservation consists of actions that reduce the demands for water, improve efficiency in use, reduce losses and waste, and improve land management practices to conserve water. The natural subsystem of water resources includes: 1) an interlinked system of rivers, estuaries, canals, khals (smaller than rivers in size), etc.; 2) the floodplain; 3) wetlands; 4) haor, baor, beel (local names of different kind of ponds filled with stagnant water), lakes, etc.; 5) ponds; 6) intertidal lands and water and 7) groundwater aquifers. However, natural reservoirs are scarce and thereby water conservation during the rainy season for dry season use is limited.

Water resources management is now a global concern, the main purpose of which is to provide adequate water for humans and the natural envi-

Received: September 29, 2006, Accepted: March 8, 2007
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ronment. Water management includes water utilization, water source conservation, monitoring and preservation of water quality. In this paper the overall status of water resources of Bangladesh and their utilization in different areas with emphasis on conservation is described based on available information.

2. Water Resources and Agricultural Information

2.1 Geographical and Water Resources Information

Bangladesh lies in the northeastern part of South Asia between 20°34′ and 26°38′ north latitude and 88°01′ and 92°41′ east longitude. The country is bordered by India on the west, north and northeast, Myanmar on the southeast and the Bay of Bengal on the south. The area of the country is 147,570 sq km. Bangladesh is the lowest riparian country of the Ganges basin, the Brahmaputra basin and the Meghna basin. Most of its area is low lying floodplain formed by the alluvial soil deposited by three great rivers, namely the Brahmaputra/Jamuna, the Ganges and the Meghna. These rivers drain a catchment area of approximately 1.72 million km^2 in India, Nepal, China, Bhutan and Bangladesh; only 8 percent of the catchment area lies within Bangladesh. These major rivers and their tributaries have their headwaters outside Bangladesh as shown in Fig. 1, with about 90% of their annual flow originating outside the country. This flow has a huge annual variation with the combined flow of the Ganges and the Brahmaputra typically increasing from less than 10,000 cumecs early in the year to a peak of 80,000 to 140,000 cumecs by late August to early September. Shortages of water in the dry season in Bangladesh are exacerbated by the diversion of water at the Farakka Barrage, just upstream of where the Ganges enters Bangladesh. The country contains approximately 22155 km of river length with approximately 700 rivers. The river system of Bangladesh is shown in Fig. 2. Rivers and water bodies occupy approximately 5% of the land surface. The land topography is almost flat with a few hilly areas in the southeastern part.

The country enjoys a tropical monsoon climate with two prominent seasons, the dry season (November-May) and the wet season (June-October). Bangladesh is predominantly an agricultural country with approximately 54% of the lands used for crop production. Up to 85% of the annual rainfall occurs between June and September. Mean annual rainfall ranges from approximately 1200 mm in the west to almost 6000 mm in the northeast. The average annual rainfall in the Himalayas and in the Meghalaya hills to the north of Bangladesh reaches approximately 10,000 mm.

Approximately 25% of the country is flooded to varying degrees each year during May through September when over 60% of the cereals are produced. Recurrent flooding severely restricts the farmers' choices of cropping to traditional low yielding broadcast varieties of rice that can thrive in deep water, in fact, this coverage is dominated.

Fig. 1. The Ganges, Brahmaputra and Meghna River Basins

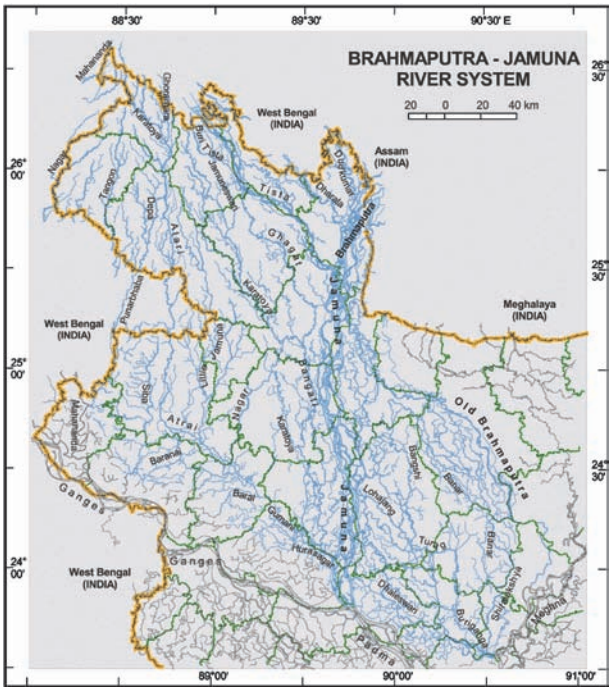

Fig. 2. River systems in Bangladesh

The real production potential is not harnessed due to flood depth. On the other hand, scarcity of irrigation water during March through April limits the cultivation of high yielding varieties of rice that accounts for approximately 36% of the total rice production.

2. 2 Problems for Bangladesh as a Lower Riparian in the Basins

As the lower riparian region of the major rivers, Bangladesh is located at a point of concentration for monsoon floods generated by runoff from the Himalayas. Continued development of upstream basins increases the disadvantages of being in the lower riparian region and floods are likely to increase because of deforestation of the Himalayas, land degradation and erosion. On the other hand, during the October to May dry period Bangladesh receives only residual flow after diversion and upstream use. Reduction of the dry season flows in Bangladesh due to increasing upstream withdrawal causes severe water shortages across the country and particularly in the south west region. Reduced stream flow also aggravates salinity intrusion and environmental degradation.

2. 3 Agricultural Information

The landscape of Bangladesh is broadly grouped into three land forms. These are hill areas accounting for 12%, terrace areas covering 8%, and floodplain areas covering 80%. The total land area of Bangladesh is 14.8 million hectares of which 9.5 million hectares are available for cultivation and 7.5 million ha are subject to potential irrigation. Six million ha are subject to flooding ranging from 30 cm to in access of two meters. The time of arrival, depth, duration of flooding and the rate of rise largely determine the choice and timing of crops.

Diversified cropping has been practiced in Bangladesh from time immemorial. Cropping patterns are essentially rice based and most non-rice crops are grown in sequence with rice in one or even two seasons. Apart from different varieties of seasonal rice, non-rice crops grown in the country include nearly a hundred types of fruits, vegetables, pulses, oilseeds, spices, jute, sugarcane, potato, tobacco, millets, wheat etc. Agro-climatic conditions in the kharif season (April-July/August) favor rice, whereas non-rice crops with the exception of jute can not be grown during this season. Most non-rice crops are grown in the rabi season (December-May) when the hydrological regime is the major factor in the selection of crop type.

3. Sources of Water in Bangladesh

In Bangladesh, the sources of water are surface water and ground water. Both sources may be fresh or saline.

3. 1 Surface Water

Surface water sources are categorized as rainfall, transboundary flow, water in standing water bodies (water storage in reservoir, water bodies such as river, lake and pond), water in seasonal wetlands, and in-stream storage. These are described below:

i) Rainfall

Average annual rainfall of the country is approximately 2360 mm (1960–1997). Yearly variation of annual rainfall is shown in Fig. 3. Regional distribution of annual rainfall is shown in Table 1.

This table shows that northwest and southwest regions of the country receive less rainfall than other areas of the country. Approximately 20% of the average annual rainfall occurs in the dry season

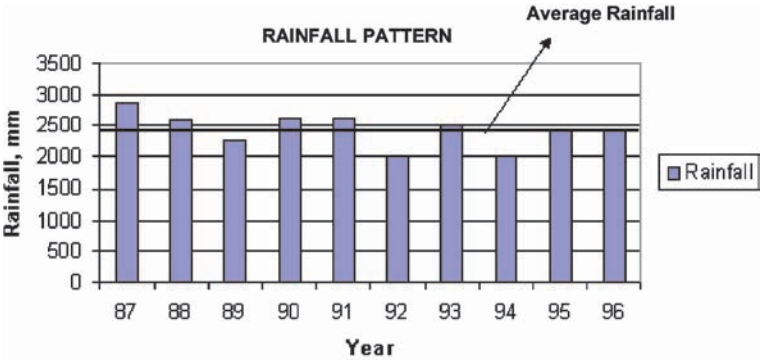

Fig. 3. Variations in annual rainfall of Bangladesh (Source: Ahmed, 1999)

Table 1. Rainfall of Bangladesh in mm

Season	Region of the Country							Average
	NW	NC	NE	SW	SC	SE	EH	
Wet	1393	1445	2297	1299	1821	1683	1934	1856
Dry	346	511	897	366	486	588	511	504
Annual	1739	1956	3194	1665	2307	2271	2445	2360

NW-North West, NC-North Central, NE-North East, SW-South West, SE-South East, SC-South Central, EH-Eastern Hills

Table 2. Peak and lean flow in the major rivers

River	Station	Peak flow (m^3/s)	Lean flow (m^3/s)	Lean flow (% of peak)
Ganges	Hardinge Bridge	76000	526	0.7
Brahmaputra	Bahadurabad	102534	2860	2.79
Meghna	Bhairab Bazar	19800	—	—

(November-May) in the northwest region but the monthly distribution of this rainfall is highly uneven.

ii) Transboundary flow

Bangladesh shares 57 transboundary rivers, 54 incoming from India and 3 from Myanmar. Among the rivers, the Ganges, the Brahmaputra and the Meghna drain approximately 1.08 million sq km, 0.58 million sq km and 0.09 million sq km respectively. Total annual volume of water that enters the country from the transboundary rivers is approximately 1000 billion m^3. Although this amount seems high, its contribution in the critical month of February is only 1% of the total showing the vulnerability of the transboundary flow to meet water demands during the dry season. Striking features of the transboundary flow are the differences between the peak flow and the lean flow as shown in Table 2.

In almost all the shared rivers, except the three major rivers, a no flow situation prevails during the driest period of the year. The crucial issue of the transboundary flow is the diminishing inflow to Bangladesh during the dry season. Due to indiscriminate and unilateral upstream withdrawal of water of the common rivers during the dry period when the country needs water (in absence of any rainfall), a water crisis situation prevails in Bangla-

desh. The southwest part (Ganges Dependent Area) of the country is the most affected region due to upstream withdrawal of the Ganges at Farakka, where irreversible environmental degradation is happening. On the other hand, peak monsoon flow often causes floods in Bangladesh. In a normal year, approximately 20% of the country is inundated, which in extreme cases may rise up to 60% (example 1987, 1988, 1998 floods).

iii) Water in Standing Water Bodies

In addition to natural rivers, water is retained in localized low pockets (beels/baors) and ponds for the dry season. Kapatai lake is the only reservoir in the country that has a storage capacity. Total volume of the standing water bodies is approximately 0.61 billion m^3.

iv) Water in Seasonal Wetlands

Floodplains (approximately 80% of the total area of the country) become seasonal wetlands during the monsoons (July-October) because of slow drainage of huge transboundary flow and local rainfall excess. The seasonal wetlands remain inundated from a few days to as long as several months (May-November). Estimated volume of water stored in these seasonal wetlands/floodplains is approximately 2.69 billion m^3. This seasonal storage provides virtually no contribution during the dry season.

v) In-stream Water Storage

Numerous channels criss-crossing the entire country store water in the rainy season until they become completely dry. Estimated volume of channel storage is approximately 0.5 billion m^3.

3.2 Groundwater

The main source of ground water is the recharge from surface water. Most of the areas of Bangladesh have been formed from the sedimentary alluvial and deltaic deposits of the three major rivers. These alluvial deposits have formed mainly an unconfined aquifer for most of the area of the country. Groundwater was supposed to be one of the major natural resources of the country for safe drinking water supplies. However, the presence of arsenic in the shallow aquifer has completely changed the situation. It is estimated that approximately 16% of the present population of 123.15 million is exposed to arsenic contamination exceeding Bangladesh standards (0.05 mg/l). Approximately 74452 sq km of groundwater use area (50% of the country) is unsuitable for use as hand tubewells (as a source of drinking water according to WHO standards) due to arsenic contamination. The volume of water occupied by these important sources are shown in Table 3.

4. Water Availability and Problems

4.1 Surface Water Availability and Problems

The natural surface water resources in Bangladesh are mainly derived through the major river systems and their tributaries. The flow distribution characteristics in the river system are a combination of upstream inflows and run-off generated from rainfall within Bangladesh. In the southern regions, the distribution is also affected by tidal conditions.

Surface water is abundant in the wet season in Bangladesh. An estimated 795,000 million cubic meter (Mm^3) of surface water is discharged per year through the Ganges-Brahmaputra system, downstream of the confluence of the Ganges and the Brahmaputra. This is equivalent to 5.52 m deep water over a land area of 144,000 km^2. There are other rivers discharging surface water into the Bay of Bengal. In the dry season, Bangladesh suffers from acute shortages of both surface and groundwater (BUET, 2004).

Bangladesh experiences four main types of floods: monsoon floods from the major rivers; local flooding due to drainage congestion; flash floods in the eastern and northern rivers; and floods caused by high tides and storm surges in the coastal areas.

Table 3. Volume of water occupied by the important sources

Source	Transboundary	Rainfall	Groundwater
Volume in million cubic meter	1,050,000	343,000	23,000
Volume in percent	74%	24%	2%

During the June-September monsoons, Bangladesh receives approximately 80% of its annual precipitation, averaging 2300 mm, but varying from as little as 1200 mm in the west to over 5000 mm in the east. Runoff from adjacent riparian systems is generated by rainfall that averages 5000 mm over the Himalayas, and exceeds 10,000 mm over the Meghalaya plateau north of Sylhet. Together inflows and rainfall cause peak floods in the Ganges, Brahmaputra and Meghna rivers during the period of July-August, and an average 22% of the country is flooded annually.

Drought is also a problem in Bangladesh, particularly in the north west regions during the spring when there are few surface water resources, and agricultural production is heavily reliant on groundwater resources. However, drought is not only confined to the dry season, and scanty rainfall during the monsoon, as happened in 1994, but also severely affects floodplain fisheries and late monsoon aman rice. Groundwater recharge for the subsequent dry season is also adversely affected.

4.2 Groundwater Availability and Problems

Groundwater is the main source of water supplies in urban and rural areas of Bangladesh. Except for a few hilly regions, Bangladesh is entirely underlain by water bearing aquifers at depths varying from zero to 20 m below the ground surface. Groundwater in Bangladesh is available in adequate quantities, but the availability of groundwater for drinking purposes has become a problem for the following reasons (BUET, 2004):

- Arsenic in groundwater;
- Excessive dissolved iron;
- Salinity of the shallow aquifers in the coastal areas;
- Lowering of groundwater level;
- Rock/stony layers in hilly areas;

Therefore, it may be said that in spite of heavy rainfall, readily accessible groundwater and large river systems in this country, at present water scarcity for drinking purposes is the major problem in Bangladesh due to arsenic contamination in groundwater and surface water pollution from point and non-point sources.

4.3 Water Resources Development

On an annual basis, the water theoretically available to Bangladesh is huge in relation to demands. The annual rate of reference crop evapotranspiration (ET_0) is approximately 1500 mm/year and the annual average rainfall is some 2200 mm. In addition, a volume of some 1010 billion m^3 enters the country in the 57 rivers that cross its borders with India and Myanmar, which corresponds to a further 6800 mm over its surface of 147,570 km^2, for a total of 9000 mm, four times the ET_0. Regional balances of rainfall and evapotranspiration as presented in Table 4 show water abundance in the wet season and shortages in the dry season.

The surface water available for development in the regional rivers during the dry season (November to May) was estimated by the Master Plan Organization (MPO) for the period 1989–1990 as shown in Table 5. These figures are small when divided by the net cultivable area (NCA in Mha) in each region, and compared with the ET_0 as shown in Table 6. In the south west, the surface water of 7 mm available in March and the dependable rainfall of 27 mm together amount to only 22% of the ET_0. However, there is a large groundwater reservoir that is replenished by monsoon rainfall and flooding and is tapped by shallow tubewells (STW)

Table 4. Regional balance of rainfall and evapotranspiration

Region	Rainfall, mm		Evapotranspiration, mm		Deficit, mm	
	Wet	Dry	Wet	Dry	Wet	Dry
NW	1881	156	795	679	−1116	523
NE	2594	368	776	700	−1818	432
SW	1792	183	816	719	−974	536
SE	2661	260	866	785	−1795	525

Table 5. Surface water available for development by volume (1989–1990)

Surface water available for development (Mm^3)							
Region	Nov	Dec	Jan	Feb	Mar	Apr	May
NW	2,970	1,840	1,160	780	780	920	2,210
NE	5,090	1,710	710	130	230	2,480	9,680
SE	820	950	750	640	650	630	1,090
SC	8,250	4,440	3,050	2,020	2,320	3,760	7,680
SW	1,180	580	270	140	120	100	230
Total	18,310	9,520	5,940	3,710	4,100	7,980	20,890

Table 6. Surface water available for development by depth (1989–1990)

Surface water available for development (mm of cultivable area)								
Region	NCA (Mha)	Nov	Dec	Jan	Feb	Mar	Apr	May
NW	2.451	121	75	47	32	32	38	90
NE	2.573	198	66	28	5	9	96	376
SE	1.313	62	72	57	49	50	48	83
SC	1.026	804	433	297	197	226	366	749
SW	1.666	71	35	16	8	7	6	14
ET_0	—	102	87	88	107	155	175	180

during the dry season.

5. Water Demand and Supply

Demands on water arise from several factors such as natural (evapotranspiration), water supply, irrigation, fisheries, livestock, industry, navigation and the environment (demands for salinity control). Proportions of total water demands as projected for 2025 are estimated to be; instream-56%, agriculture-32%, environment-9% and water supply-3%. Therefore, consumptive use is 44%. Environmental flow requirements according to International Union for Conservation of Nature and Natural Resources (IUCN) as stated by Saleh (2003) be should at least 30% of the world's river flows in order to maintain fair conditions of freshwater ecosystems.

If we compare the rainfall and reference crop evapotranspiration we can see the situation of water demand and supply. The reference crop evapotranspiration and rainfall during the critical months (when it exceeds the rainfall) is given by region in Table 7, which shows that supply of water during the driest periods in the whole country is much lower than the demands. Water demands for agriculture amount to approximately 70% of the global withdrawal but for Bangladesh the figure is approximately 80% (November to March withdrawal). Water use for agriculture in Bangladesh increased by 2.73 times in 2001 relative to 1991 according to International Rice Research Institute (IRRI) as reported by Saleh (2003).

Water balance on a yearly basis shows a clear deficit for the entire country. This picture is alarming if the same is considered for the driest period of the year. In the absence of significant storage for water in Bangladesh, water balance calculations are normally made on a monthly basis. Table 8 shows the projected demand and supply in the month of March in 2018 according to MPO (1991). Still the

Table 7. Regional monthly ET_0 and rainfall (mm)

ET_0/Rainfall Region	Nov	Dec	Jan	Feb	Mar	Apr
SE	80/39	65/11	70/6	86/24	132/60	—
NW	79/12	65/7	67/8	85/11	136/22	164/72
NC	80/23	66/11	70/6	87/21	136/40	159/127
RT	83/38	70/11	74/6	90/20	136/48	157/130
SW	84/31	72/11	76/9	92/23	145/36	173/80
NE	78/32	65/13	68/9	85/31	128/82	—
SC	81/53	71/11	75/7	90/23	135/46	152/115
EH	88/59	79/11	85/5	98/17	140/44	153/124

Table 8. Projected water supply and demand in the month of March

Projected water supply and demand, March 2018 (MPO 1991)					
Water requirements	Mm^3	%	Water supplies	Mm^3	%
Agriculture	14,290	58.6	Main rivers	11,740	50
Navigation, Environment and Fisheries	9,910	40.7	Regional rivers	6,390	27
Domestic uses and industry	170	0.7	Groundwater	5,360	23
Total	24,270	100	Total	23,490	100

projected water supply is found to be less than demand.

6. Water Conservation and Regional Development Options

Water conservation is necessary for agriculture, hydropower, recreation, the environment and preservation of wetlands. The overall agricultural policy objective for Bangladesh is to expand and diversify agricultural production and to maintain food security, especially with regard to sustaining near self-sufficiency in rice. Irrigation has been the major water sector contributor to agricultural growth. Groundwater irrigation is limited to approximately 56% of the country and the main concerns are whether this needs to be curtailed due to possible arsenic contamination. Surface water is the cheapest form of irrigation if water is available nearby in sufficient quantities. Surface water is applicable to 44% of the country where groundwater is not available and to areas where groundwater deficits may be expected due to low recharge or arsenic limitations.

Most of the NE, SE and SW regions are dependent upon surface water. Parts of the NW and NC regions also require surface water. First priority can therefore be assigned to the development of surface water resources in the SW by utilizing the Ganges waters and second to the NE and SE regions by utilization of Meghna waters. Through the development of barrages on the Jamuna, Ganges and Padma water resources can be conserved to use in the dry season. Such development in the eastern hills is also needed as this region has little groundwater. Higher dry season water levels in the reservoir will ensure lower irrigation water pumping costs, rises in dry season groundwater levels in land adjacent to the reservoir and in-

creased water levels will increase water retention of ponds adjacent to the river. Region-wise water-related issues have been sorted out in a National Water Management Plan to address the problems in the future as presented in Table 9.

A National Water Policy has been undertaken to address the above issues by:

- Harnessing and development of all forms of surface and groundwater and management of these resources in an efficient and equitable manner.
- Ensuring the availability of water to all.
- Accelerating the development of sustainable public and private water delivery systems.
- Developing a state of the art knowledge and capabilities that will enable the country to design future water resources management plans.

The Water Resources Planning Organization (WARPO) is an organization that was created in 1992 to perform planning of water resources by:

- Preparing an environmentally compatible master plan for water resources development.
- Formulating strategies and policies for scientific utilization and conservation of water resources.
- Assisting organizations/agencies involved in utilization, conservation and development of water resources by conducting studies and, if necessary, special studies on any related issues.
- Collecting and analyzing data and information on water resources and arranging for dissemination of the information.

7. Conclusions

Due to its geographical location, Bangladesh experiences water abundance during the wet season and lack of water during the dry season. These are two major conflicts in water resources management of the country. These two major conflicts can be overcome by conserving required amounts of water for the dry season during the wet season by building more barrages across the rivers as well as by

Table 9. Region-wise water related issues

Region	Issues
SW	Preservation of the Sundarbans, restoration of dry season fresh water inflows, maintenance of the coastal embankment system, alleviation of coastal drainage congestion, improved cyclone protection, flood proofing in the low lying areas
NE	Environmental management of the Haor basin, flood proofing, erosion of old Brahmaputra left bank, drainage congestion in the rivers, hill irrigation
NC	Bulk water supplies and pollution control in Dhaka City, flooding and drainage problems, flood proofing in low lying areas
NW	Erosion along the right bank of the Brahmaputra, flooding and drainage problems, drought in the western fringes, flood proofing in the low lying areas
SC	Siltation and drainage congestion, improved cyclone protection, flood proofing in low areas
SE	Gaseous aquifers, cyclone protection, drainage congestion, protection of newly accreted lands against tidal flooding
Eastern Hills	Small scale irrigation development, mini-hydro power development, improved cyclone protection,
Rivers and Estuary	Erosion protection, regional augmentation, flood proofing, cyclone protection in Meghna estuary, erosion of Meghna river, protection of newly accreted lands

dredging or developing the rivers and spilling additional amounts of water. The water conservation practices in Bangladesh still need attention as the country is geographically dislocated. Moreover, cooperation among the co-basin countries is necessary for sharing of transboundary river flows. For instance, if appropriate measures are not taken urgently to restore rightful share of the Ganges to Bangladesh, it may face further morphological and environmental hazards especially in the southwestern part of the country. Diversion of water from the Meghna at the Barak dam could have effects on the eastern region. Efficient water and flood management and assured shares from the dry season flows of the transboundary rivers have become imperative for the survival of Bangladesh. Interception of flood waters by upstream storage is crucial need for augmentation of dry season flows, power generation, comprehensive development and harnessing of water resources in Bangladesh.

8. Recommendations

As the lower riparian state of three major river systems, Bangladesh should work with its neighbors towards overall basin management with an early focus on the different hydrological regions and promoting information exchange. Although the signing of the Ganges Water Treaty in 1996 is an important milestone, continued efforts are needed to secure Bangladesh's share of the flows of the other 53 transboundary rivers. The National Water Management Plan has to address and balance the conflicting needs of too much water during monsoons and too little water during the dry season that requires tapping of the resources of both surface and groundwater.

Acknowledgements

The authors are grateful to the Water Resources Planning Organization (WARPO) of Bangladesh for supplying the necessary data and information for preparing this paper.

References

Ahmed, M.F., 1999. Rainwater harvesting potential in Bangladesh, Proceedings of the WEDC Conference on Integrated Development of Water Supply and Sanitation, Addis Ababa, Ethiopia, 363–365.

BUET*, 2004. Water Supply Situation Analysis, Online Publication (URL: http://www.buet.ac.bd/itn/publications/as_mitigation/as_mitigation_part4_2.pdf), Bangladesh University of Engineering and Technology, Dhaka, Bangladesh.

MPO, 1991. National Water Plan, vol-2, Master Plan Organization, Ministry of Irrigation, Water Development and Flood Control, Government of the People's Republic of Bangladesh.

Saleh, A.F.M., 2003. Lecture notes on Water Management and Agriculture, Short course on Integrated Water Resources Management, BUET, Dhaka, 18 pp.

*: Bangladesh University of Engineering and Technology