

HARNESSING WATER RESOURCES IN THE NEXT CENTURY FOR BANGLADESH AGRICULTURE

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ABSTRACT

Water is an essential component of sustainable agriculture. Rainfed agriculture in Bangladesh is risky, while irrigation is expensive but profitable. Quality irrigation water is a scarce resource during the dry season. Efficient irrigation technologies should be used/developed to make best use of this resource. Rice requires a huge quantity of water, and on the other hand, wetland agriculture is said to be a major factor for emission of CH₄, CO₂ and other greenhouse gases. Therefore, the number of rice crops in a pattern should be reduced and substituted with other economically important crops. If more environment friendly irrigation techniques and crop types are given a higher priority, water use could be dramatically reduced, resulting in more sustainable development.

Keyword: Water, Agriculture, Rainfed agriculture, Irrigation

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INTRODUCTION

Water is an essential component of sustainable agriculture. For rainfed or irrigated crop cultivation, livestock production, fisheries, and forestry development an adequate supply of good quality water is essential. Crops in Bangladesh are predominantly rainfed, depending heavily on a spatially and temporally uneven distribution of annual rainfall ranging from <1400 mm in the northwest to >5000 mm in the northeast regions (Manalo, 1976). About 90 percent of the rainfall occurs in the monsoon from June to September. Due to scanty rainfall in other months, in areas with low soil moisture content and physical soil constraints to tillage, crop diversification is hampered considerably (Karim *et al.*, 1986). Anticipated climate change may make the rainfall patterns of the country even more irregular and unreliable. Karim *et al.*, (1990) reported that due to irregular and unreliable rainfall, *rabi* crops in general suffer from moisture stress. Yield reductions are not because of drought only but also due to breakdown of irrigation facilities. Proper irrigation plays a vital role in crop production in the country and will be of more importance in the future, when the scarcity of fresh or irrigable water is feared to increase. Another complexity is the occurrence of a large variety of soils and landtypes in Bangladesh. The soils vary conspicuously with respect to moisture holding capacities, infiltration rates, and other related properties (Karim *et al.*, 1990). Therefore, more emphasis should be given to low water consuming agriculture.

During the past three decades irrigated agriculture has played a major role in total rice production. In the fiscal year 1992-93 the total irrigated area was 3.25 Mha (million hectare) among which 2.42, 0.43, and 0.17 Mha were irrigated by modern, traditional and canal methods, respectively. Currently, about 26.6 % of the total rice grown in the country are irrigated. During the *boro* season rice is primarily an irrigated crop, occupying about 71.3% of the total irrigated area (BBS, 1995).

According to the National Water Plan the total gross water demand in the dry season (March) is 25,697 Mm³ (9,588 m³ s⁻¹) which includes 16,155 Mm³ for agricultural use. Total water supply in this month is 25,101 Mm³ that comprises 6,872 Mm³ of groundwater, 5,652 Mm³ from regional rivers, 741 Mm³ from storage in beels (natural lakes) and haors (permanently wet basin areas), and 11,736 Mm³ from main rivers. The Master Plan Organization (MPO) about a decade ago estimated water resource potential and a considerable growth has taken place on the use of surface as well as groundwater since then (MPO 1987). With the present high implementation rates there are trends in seasonal declines in water tables and low capacity utilization of irrigation systems. This warrants immediate evaluation of the potential of groundwater resources and the development of low water consuming agricultural production technologies.

To address these problems some suggestions, policy considerations, and possible interventions are presented in this article.

AGRO-ECOLOGICAL SETTINGS

Various relevant factors and sub-systems that influence the agricultural production systems are discussed in the following sections.

Agro-ecological Regions

In Bangladesh 30 agro-ecological regions are recognized. These regions were delineated by adding successive layers of relevant information for assessment of the agricultural potentials (UNDP/FAO, 1988). The information layers are:

- physiography;
- depth and duration of seasonal flooding;
- length of rainfed *kharif* and *rabi* growing periods;
- length of the pre-*kharif* growing period of unreliable rainfall;
- length of cool winter period;

- frequency of occurrence of extremely high (>40°C) summer temperatures.

Table 1 shows the area under different agro-ecological regions and their landtype-wise distribution. About 41.1% of land excluding areas occupied by homesteads and water bodies is Medium Highland, 34.2% is Highland, and 14.3% and 10.4% are Medium lowland, and Lowland, respectively. Table 1 also indicates that the Tista Meander Floodplain (7.0%), Young Brahmaputra and Jamuna Floodplain (4.2%), Old Brahmaputra Floodplain (5.3%), High Ganges River Floodplain (9.6%), Low Ganges River Floodplain (5.8%), Ganges Tidal Floodplain (11.4%), Old Meghna Estuarine Floodplain (5.2%), and Northern and Eastern Hills (14.0%) together account for more than 62% of the land area. The cropping patterns that exist in the country are influenced by the above mentioned agro-ecological parameters. While these factors are not controllable, some agronomic manipulations are possible. Among these factors physiography, and depth and duration of flooding are most important.

POSSIBILITIES AND CHALLENGES

Surface Water

Although there is potential to increase irrigated areas from development of main river water, and from development of regional surface water, the area under major irrigation has virtually not increased in the last five years. Most of the present large-scale gravity irrigation systems are operating at much below the planned capacity, mainly because of poor operation and maintenance. The cost of irrigation has also increased substantially with rapid deterioration of existing facilities. The future development of surface water would require a large amount of public investment.

Groundwater

In Bangladesh, groundwater tables are generally at shallow depth. Recharge conditions are favourable in 80 per cent of the alluvial basin due to heavy monsoon rains and prolonged inundation. The high permeability of the aquifers and the quality of water contained by the systems are good, with the exception of brackish and saline groundwater in the coastal zone.

Groundwater irrigation accounted for 69 percent of the total minor irrigation command area in 1994 (MOA/FAO, 1995). In most parts of Bangladesh, these shallow aquifers are hydraulically connected to surface water sources.

The Master Plan Organization has estimated the present annual utilization of groundwater to be about 8500 Mm³ and indicated that there exists a vast potential for future irrigation development using groundwater (MPO, 1990). Validity of these model-based estimates has been questioned by concerned agencies because of controversy about certain critical variables used in the model. Groundwater development has equity implications because all modes of water extraction are not suitable for all aquifers and all aquifers would not give the same output (Shahjahan, 1994). Over-extraction or mining of groundwater should be checked in order to avoid lowering of water table and deterioration of water quality.

Table 1. Area Under Different Agro-ecological Regions And Their Landtype-Wise Distribution (Thousands of hectares).

Agro-ecological Region	Highland	Medium Highland	Medium Lowland	Lowland	Total land area	Homestead and Water bodies	TOTAL area
Old Himalayan Piedmont Plain	232.5	136.3	4.0	0.0	372.7	28.1	400.8
Active Tista Floodplain	1.7	59.8	0.0	0.0	61.4	21.6	83.0
Tista Meander Floodplain	331.4	482.9	37.9	9.5	861.6	85.2	946.8
Karatoya-Bangali Floodplain	59.2	113.2	36.0	12.9	221.2	36.0	257.2
Lower Atrai Basin	1.7	6.8	17.9	55.3	81.7	3.4	85.1
Lower Purnabhaha Floodplain	0.0	0.0	1.3	7.7	9.0	3.9	12.9
Active Brahmaputra-Jamuna Floodplain	16.0	118.0	63.8	25.5	223.3	95.7	319.0
Young Brahmaputra and Jamuna Floodplain	106.6	248.8	112.6	53.3	521.3	71.1	592.4
Old Brahmaputra Floodplain	202.4	253.1	144.6	50.6	650.7	72.3	723.0
Active Ganges Floodplain	40.0	110.0	60.0	13.3	223.4	110.0	333.4
High Ganges River Floodplain	567.8	422.6	158.5	26.4	1,175.2	145.3	1,320.5
Low Ganges River Floodplain	103.6	231.1	247.0	127.5	709.2	87.6	796.8
Ganges Tidal Floodplain	34.1	1,331.1	34.1	0.0	1,399.4	307.2	1,706.6
Gopalganj-Khulna Bils	6.7	29.2	92.1	87.6	215.7	9.0	224.7
Arial Bil	0.0	1.9	0.0	10.5	12.4	2.0	14.4

Middle Meghna River Floodplain	0.0	12.4	45.1	56.0	113.5	42.0	155.5
Lower Meghna River Floodplain	12.7	25.5	28.2	0.0	66.4	24.5	90.9
Young Meghna Estuarine Floodplain	0.0	17.1	64.9	0.0	482.0	444.9	926.9
Old Meghna Estuarine Floodplain	15.5	185.8	255.4	185.8	642.4	131.6	774.0
Eastern Surma-Kushiyara Floodplain	23.1	115.6	92.4	166.4	397.5	64.7	462.2
Sylhet Basin	0.0	18.3	86.9	301.8	407.0	50.3	457.3
Northern and Eastern Piedmont Plain	133.3	125.2	64.6	40.4	363.4	40.4	403.8
Chittagong Coastal plain	63.2	160.0	48.4	0.0	271.6	100.4	372.0
St. Martin's Coral Island	0.3	0.5	0.0	0.0	0.8	0.0	0.8
Level Barind Tract	151.5	277.7	20.2	10.1	459.5	45.4	504.9
High Barind Tract	148.8	1.6	0.0	0.0	150.4	9.6	160.0
Northern-eastern Barind Tract	38.8	60.4	1.1	0.0	100.3	7.6	107.9
Madhupur Tract	237.7	76.4	29.7	38.2	382.0	42.4	424.4
Northern and Eastern Hills	1,671.7	36.3	18.2	0.0	1,726.2	90.9	1,817.1
Akhaura Terrace	6.2	1.2	1.1	2.0	10.6	0.7	11.3
Total	4,206.5	4,658.8	1,766.0	1,280.8	12,311.8	2173.8	14,485.6

Source: BARC (1989).

Many problems have been encountered at the field level, some of which are highlighted here. As a consequence of inadequate information about aquifer characteristics and improper fielding of shallow tube wells (STW) and deep tube wells (DTW), pumps cannot draw water from the groundwater reserves even if there is enough water present in the aquifer. Jaim (1993) reported that in many areas of northwest Bangladesh excessive number of DWTs have already been sunk where SWTs can successfully operate. Installation of excessive number of DWTs and SWTs in some areas is also causing inefficiency in terms of coverage. It is feared that over-exploitation of groundwater through rapid expansion of SWTs may cause draw down effect in the near future in the North Bengal region of the country. During the dry season in the drought-prone areas of the country water tables are lowered considerably, making lifting of groundwater by SWTs impossible. In some cases, the groundwater quality for irrigation also deteriorates. Khan (1988) reported that abstraction of groundwater might entail a number of undesirable environmental consequences, such as, decline in groundwater level, salinity or water quality problems. Therefore, the current estimates should be validated at field level and if the results are satisfactory, only then should

these values be used in making groundwater extraction plans. A zoning policy may be needed and enforced in the future in order to protect the interests of the farmers investing in various modes of water extraction. Monitoring of groundwater utilization by the government agencies should continue so as to avoid over-extraction and quality deterioration.

Water Table Depths

Changes in inundation levels are reflected in changes in groundwater levels. The relationship between surface water and groundwater levels is closest in areas with unconfined aquifers: e.g., in areas where surface water and groundwater are not separated by an impervious layer. The water table depths of Bangladesh have been classified into six categories. They are:

Category	Depth (m)
I	<3
II	3-5
III	5-7
IV	7-10
V	10-15
VI	15-22

In the southern, northeastern and some parts of the northwestern regions of Bangladesh the water table depths are within 3 m from the surface. The second category (3-5 m) is dominant in the northeastern region and in some parts of upper northwestern and southwestern regions. The third category (5-7 m) is distributed along both sides of the Jamuna River and southwestern side of the Ganges River. The remaining three categories are spread over the mid-western and mid-central regions of the country where the Barind and Madhupur tracts and Akhaura Terrace are located. The extent of their occurrence is in the following order: Category IV > Category V > Category VI. The latter three categories are most drought-prone areas on the country.

Mitigation Measures

Minor Irrigation Technologies

Minor irrigation has been the engine of growth of Bangladesh agriculture. It has contributed to over two-thirds of the annual growth rate of about three percent in rice production during the past 15 years. The area with minor irrigation facilities increased from about 1.5 Mha in 1980 to 2.6 Mha in 1993-94 (MOA/FAO, 1995).

Various minor irrigation technologies are used in the country, including LLPs (low lift pumps), STWs, DTWs, DSSTWs (deep set shallow tube wells) and some manually operated pumps. Shallow tubewells account for about 53% of the total minor irrigation command area. Low lift pumps, DTWs and traditional irrigation devices contribute about 18, 15, and 13% of the total minor irrigation command area respectively. After privatization and with the abolishment of restrictive measures, STW sales increased at an annual rate of 14% growing from 159,000 in 1987 to 349,000 in 1993 (BBS, 1995).

In Bangladesh, population increase coupled with increasing consumption resulting from rising incomes will substantially increase the demand for food. With increased food production, available water will decrease and the increasingly precious commodity will be competed for by multiple users, resulting in conflicts. The looming scarcity of fresh water resources for irrigated agriculture leaves no choice but to devise means of growing crops with less water. About 7.55 Mha out of 9.03 Mha of arable land is suitable for irrigation, only about 2.57 Mha (34% of the potential irrigable land) is currently under irrigation (GOB/UNDP/FAO, 1997). Thus, there is still considerable scope for the expansion of irrigation for the agricultural development of the country with high water use efficiency and for crops requiring less water.

Cropping Patterns

Innumerable cropping patterns are practiced in the country and the agro-ecological conditions and availability of inputs govern these. **Table 2** gives the landtype-wise dominant cropping patterns in different agro-ecological regions along with their total annual irrigation water consumption. The lowest irrigation water consuming pattern is Blackgram/Wheat - B. Aus - Fallow (350 mm) followed by Onion/Water Melon/Mungbean/Cowpea/Chilli - Fallow - T. Aman (400 to 600 mm), and the highest is Boro - T.Aus - T. Aman (2,250 mm).

Crop Economics

In **Table 3** a comprehensive summary of yields and economics of some major and minor crops is presented. From the table it is evident that the highest net financial return in Taka ha⁻¹ is obtained from spices and lowest from cereals. The Benefit/Cost Ratio (BCR) is also the lowest for wheat and is closely followed by boro rice. Higher BCR is given by oilseeds, pulses and fruits. For oilseeds, pulses and fruits the average net financial return per unit of water use is > Tk.1000.

Table 2. Low Water Consuming Cropping Patterns for Different Agro-ecological Regions of Bangladesh.

	Agro-ecological Region	Dominant Land Type	Low Water Consuming Cropping Patterns	Total Water Use (mm)
1	Old Himalayan Piedmont Plain	Highland	Wheat - T. Aus - Fallow	1,090
		Medium Highland	Wheat - T. Aus - T. Aman	1,390
2	Active Tista Floodplain	Medium Highland	Wheat - T. Aus - T. Aman	1,390
3	Tista Meander Floodplain	Highland	Wheat - T. Aus - Fallow	1,090
		Medium Highland	Wheat - T. Aus - T. Aman	1,390
4	Karatoya-Bangali Floodplain	Medium Highland	Wheat - B. Aus - T. Aman	740
5	Lower Atrai Basin	Lowland	Boro - Fallow -Fallow	1,200
6	Lower Purnabhaha Floodplain	Lowland	Boro - Fallow -Fallow	1,200
7	Active Brahmaputra-Jamuna Floodplain	Medium Lowland	Boro - Fallow -Fallow	1,200
8	Young Brahmaputra and Jamuna Floodplain	Medium Highland	Potato - T. Aus - Fallow	1,280
			Blackgram/Boro - T. Aus - Fallow	
9	Old Brahmaputra Floodplain	Medium Highland	Boro - Fallow - T. Aman	1,500

10	Active Ganges Floodplain	Medium Highland	Blackgram/Wheat - B. Aus - Fallow	350
11	High Ganges River Floodplain	Highland	Wheat - T. Aus - Fallow	1,090
		Medium Highland	Wheat - T. Aus - T. Aman	1,290
12	Low Ganges River Floodplain	Medium Highland	Pulses (Chickpea/Grasspea) - B. Aus - T. Aman	1,060
13	Ganges Tidal Floodplain	Medium Highland	Onion/Water Melon/Mungbean/ Cowpea/Chilli - Fallow - T. Aman	400 - 600
14	Gopalganj-Khulna Bils	Medium Lowland	Boro - Fallow - Fallow	1,200
15	Arial Bil	Lowland	Boro - Fallow - Fallow	1,200
16	Middle Meghna River Floodplain	Medium Lowland	Boro (Local) - Fallow - Fallow	1,000
17	Lower Meghna River Floodplain	Medium Highland	Boro - T. Aus - T. Aman	2,250
		Medium Lowland	Boro - Fallow - T. Aman	1,500
18	Young Meghna Estuarine Floodplain	Medium Highland	Boro - Fallow - T. Aman (LIV)	1,200
19	Old Meghna Estuarine Floodplain	Medium Lowland	Boro - Fallow - T. Aman	1,500
20	Eastern Surma-Kushiyara Floodplain	Lowland	Boro - T. Aus (LIV) - T. Aman	2,200
21	Sylhet Basin	Medium Lowland	Boro - Fallow - Fallow	1,200
22	Northern and Eastern Piedmont Plain	-	-	-
23	Chittagong Coastal plain	Medium Highland	Fallow - T. Aus - T. Aman	1,050
24	St. Martin's Coral Island	-	-	-
25	Level Barind Tract	Medium Highland	Boro - Fallow - T. Aman	1,500
26	High Barind Tract	Highland	Boro - Fallow - T. Aman	1,500
27	Northern-eastern Barind Tract	Medium Highland	Boro - Fallow - T. Aman	1,500
28	Madhupur Tract	Medium Highland	Boro - Fallow - T. Aman	1,500
29	Northern and Eastern Hills	Highland	Vegetables - T. Aus - T. Aman	1,350
30	Akhaura Terrace	-	-	-

Table 3. Yields and economics of some major and minor crops of Bangladesh.

Crops	Yield (ton/ha)	Net financial return ¹ (Tk/ha)	Benefit/Cost ratio	Average Irrigation/water requirement ² (mm)	Average Net financial return per unit of water use (Tk/ha/cm)
FIELD CROPS					
HYV Boro rice	4.36	7,697	1.5	1,200-1,500	64-51
Wheat	2.16	2,774	1.3	340	82
Maize	3.69	19,980	2.4	490	408
HYV mustard	1.85	13,137	2.2	150	876
Groundnut	3.02	31,090	2.8	150	2,073
Sunflower	2.77	27,338	3.4	606	451
HYV Lentil	1.02	8,111	2.5	180	451
Chickpea	0.95	5,898	1.7	160	369
Pea	0.82	5,872	2.6	160	367

¹ World Bank, 1995.

² Average irrigation requirement/water requirements were calculated considering all influencing factors at moderate levels.

Blackgram	1.17	8,887	3	160	555
SPICES					
Chilies	2.93	23,187	3.7	455	510
Garlic	7.38	81,374	3	379	2,148
Onion	10.5	56,655	3.6	341	1,662
FRUITS					
Bananas	24.78	234,647	3.8	1515	1,549
Watermelon	37.97	56,934	2.3	417	1,366
VEGETABLES					
HYV Potatoes	19.17	20,260	1.6	530	382
HYV Sweet potato	26.62	33,986	2.6	230	1,478
Brinjal	18.48	95,202	4	341	2,793
Cabbage & Cauliflower	20	62,000	2.5	303	2,046

POLICY CONSIDERATIONS AND CONCLUSIONS

Bangladesh has a large agro-economic potential for a wide variety of crops including oilseeds, tuber crops, spices, fruits and vegetables. For market driven agriculture, a shift from rice production to some other low water demanding food and cash crops, which are economically favourable and well suited to our agro-ecological conditions, deserves priority consideration. Therefore, future thrusts to harness water for the next century, agriculture should encompass the followings:

- a) Flood irrigation methods are expected to retain their popularity in the foreseeable future. Comparatively high efficiency can be achieved with surface systems by land grading, tail water recycling and on-farm storage etc. Public sector investment would be needed for the purpose.
- b) In general, irrigation potentials are operative only in dry Rabi season. To maximize agricultural production and to make the system viable, they should be kept operative round the year to cover both primary and supplementary irrigations.
- c) The dry winter season (*rabi*) offers the best potential for effective use of minimum tillage as a management practice. Crops that appear to have a great potential for minimum tillage under rainfed conditions include wheat, cowpea, field pea, chickpea, lentil, grasspea and

water melon. Minimum tillage has been utilized by farmers of Bangladesh for many years with such practices as over-seeding mustard and pulses immediately after harvesting of transplanted Aman rice crop.

- d) Operation and maintenance of large-scale gravity irrigation system (surface water) must be improved through interdisciplinary on-farm evaluation. Significant opportunities exist for establishing devices that will allow better rainwater utilization.
- e) Wet-seeded and semi-dry rice systems have been found to be superior in water use efficiency. Wet seeded rice production needs 20-25% less water than transplanted rice system. Wide application of the system is necessary through an efficient extension programme.
- f) Maintaining a saturated soil regime can save about 40% of the total water normally used for wetland rice production; high rice yields do not require continuous field submergence. Dissemination of the idea is essential.
- g) For light textured soils, which are not suitable for irrigated HYV rice cultivation but potentially suitable for a wide variety of high value winter crops and T. Aman rice, supplementary irrigation may be practiced. System development and crop restructuring should be encouraged.
- h) During the dry season and in areas of declining water tables, DSSTWs have a strong potential, provided the cropping patterns are restructured with more low water consuming crops. In some selected zones where shallow aquifers do not assure adequate water supply, DTWs should be installed. To make DTW irrigation profitable, price incentives on DTW, supply of electricity and maintenance along with spare parts should be done by public sector organizations. Determining aquifer properties and development of a system of conjunctive use of surface and groundwater is essential.
- i) Privatization policy has had a positive impact but its benefit to the rural population in terms of equity has been disproportionate. It would be necessary to safeguard the interest of the poor farmers.

By the year 2030, the demand of foodgrains will stand at around 45 million tons and the demand of other crops like pulses, oilseeds sugar and vegetables will be three to four times the present consumption. Under increased demand and population pressure by drawing a comprehensive plan adhering to the above policy considerations, Bangladesh can make better utilization of her hydrological resources and can get a 'better harvest' while sustaining agricultural productivity and satisfying the demand of the increasing population.

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