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Situation Analysis on Water, Food Security, Poverty

DIALOGUE FOR SUSTAINABLE MANAGEMENT OF TRANS-BOUNDARY WATER REGIMES IN SOUTH ASIA

ECOSYSTEMS FOR LIFE

Situation Analysis on Water, Food Security, Poverty

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Preface

Bangladesh and India share three major river systems: the Ganga, the Brahmaputra and the Meghna. Along with their tributaries, these rivers drain about 1.75 million sq km of land, with an average runoff of 1,200 cu km. The GBM system also supports over 620 million people. Thus, the need for cooperation on trans-boundary waters is crucial to the future well-being of these millions.

That is precisely the motivation for the *Ecosystems for Life: A Bangladesh- India Initiative* (Dialogue for Sustainable Management of Trans-boundary Water Regimes in South Asia) project. IUCN wishes to promote a better understanding of trans-boundary ecosystems between Bangladesh and India, by involving civil society in both counries and by providing a platform to discuss issues common and germane to the region. The overall goal is an improved, integrated management of trans-boundary water regimes in South Asia. The *Ecosystems for Life* is guided by a Project Advisory Committee (PAC) of eminent persons from Bangladesh and India. This four-and-a-half year initiative is supported by the Minister for European Affairs and International Cooperation, the Netherlands.

Ecosystems for Life will develop, through dialogue and research, longer-term relationships between various stakeholder groups within and between the countries. It will develop a common understanding to generate policy options on how to develop and manage natural resources sustainably such that livelihoods and water and food security improve. Inter-disciplinary research studies will be conducted by bringing together experts from various fields from both countries so that relevant issues are holistically grasped.

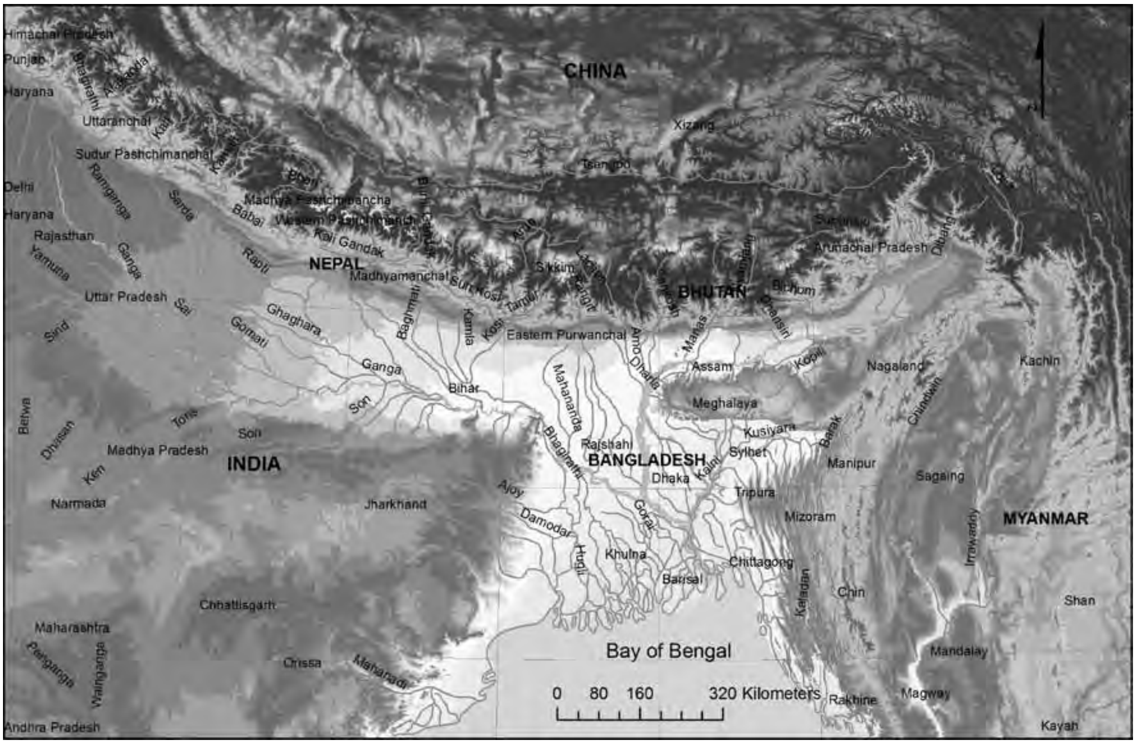
The initiative centres around five broad thematic areas:
- food security, water productivity and poverty;
- impacts of climate change;
- inland navigation;
- environmental security; and
- biodiversity conservation.

The first phase of the project concentrated on creating 'situation analyses' on each thematic area. Each analysis set identified core issues vis-a-vis a thematic area, their significance within the India-Bangladesh geographic focus, research gaps and needs and, ultimately, priority areas for joint research.

Studies were taken up in the later part of 2010 and early 2011. Authors discussed their points-of-view at a joint exercise; they shared their research. After due PAC review, the ensuing material was further circulated among multiple stakeholders in both countries. All outcomes of this dialogic process are incorporated in the final papers. 16 situation analyses related to the five thematic areas are now complete and ready for publication. We will also subsequently publish summary briefs, based on these studies. The initiative, thus, has taken a big step; now, the agenda for meaningful joint research is clear.

IUCN hopes these publications will be useful to academics, researchers and practitioners in the GBM region.

The Ganga-Brahmaputra-Meghna (GBM) region



River	Ganga	Brahmaputra	Meghna
Length[1] (km)	2,510	2,900	210
Catchment[2] (sq km)	10,87,300	5,52,000	82,000

Total area of GBM region: 17,21,300 sq km

Source: 1. Average, based on various data; 2. Joint River Commission figures

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Distress and promise: GBM riparian states of India

Upali A Amarsinghe and Bharat R Sharma

For decades, increasing land productivity has received utmost importance in India. Higher land productivity through improved seeds, fertilizers and agronomic practices has improved national food security, increased farmers' income and reduced rural poverty. But of late water, a critical farm-input, is becoming a scarce resource in many regions. As a result, increasing productivity of agricultural water use is gaining attention. An example that best illustrates this growth and stress is the story of agriculture of the states of Punjab and Haryana—the food bowl of India. These states have high agricultural productivity, some of the lowest poverty and the highest contribution to national food security. But they also have most severe unsustainable water use patterns in the long-term (Basu 2010; Sharma *et al*, 2010). In fact, unsustainable water use patterns exist in many pockets of western and southern India, and climate change impacts can exacerbate this situation.

On the other hand, the eastern states have low land productivity, high poverty and high dependency for food from other states. Although water availability is not an issue, access to it for large number of small-holders is a major constraint in improving productivity there. Thus, "bringing the Green Revolution" to the eastern Indian states, *albeit* in a different form, is necessary and has a large potential to reduce poverty and improve food security. This requires in-depth understanding of the linkages of/between determinants of water productivity, food security and poverty. And it helps in designing regionally targeted development frameworks and policies to sustainably improve productivity, food security and economic dynamism in the trans-boundary water regimes in the Ganga- Brahmaputra-Meghna region (GBM). This situation analysis of poverty, food security and land and water productivity of the Indian portion of the GBM region is a beginning to this process.

This essay focuses only on the Indian portion of the GBM riparian states: Uttar Pradesh, Bihar, Jharkhand, and West Bengal in the Ganga basin; Assam and other northeastern states—Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura—in the Brahmaputra basin. It will proceed as follows. The next section provides the poverty profile of the riparian states and compares it with other regions. The third section shows regional foodgrain surpluses or deficits. The fourth section briefly introduces environmental hotspots in the riparian states. The fifth section has a detailed presentation on physical and economic water scarcity.

Overview of the GBM region

India and Bangladesh share the vast areas of the river basins of the Ganga, the Brahmaputra and the Meghna. Most of the water from all the three basins drain into Bangladesh and finally into the Bay of Bengal. The GBM region stretches across Bangladesh (7.4%), India (62.9%), Nepal (8%), Bhutan (2.6%) and China (19.1%). Mean annual precipitation is 1,200 mm and 2,300 mm in the Ganga and Brahmaputra-Meghna river basins respectively. The system carries a peak flow of 141,000 cubic metres/second at its estuary, emptying about 1,150 billion cu m of water into the Bay of Bengal. The composite basin drains an area of 1,086,000 sq km. The estimated GBM population in 2005 is 690 million (75.8% in India; 20% in Bangladesh; 3.5% in Nepal; 0.2% in Bhutan; and 0.2% in China). In spite of its rich heritage and tremendous development opportunities, the basin is home to the largest concentration of poor in the world, with half of its population living in extreme poverty. With fertile alluvial lands in the plains (79.8 million ha) and a favourable climate, the majority of the population subsists on agriculture. Labour resources and opportunities for development are plentiful in the basin and need immediate attention.

The Brahmaputra is also one of the major rivers of Asia with its origin in southwestern Tibet as the Yarlung Tsangpo. It continues its long path (2,900 km) in southern Tibet as Dihang, in Assam valley (India) as the Brahmaputa and finally in Bangladesh as the Jamuna. There it merges with the Ganga to form a vast delta and is an important source for irrigation and transportation. The Meghna is formed inside Bangladesh by different rivers originating from the hilly regions of eastern India. It joins the other two rivers and the three together form the Ganga Delta, the largest on Earth. The Meghna is the widest river, as much as 12 km wide at the point near Bhola. Despite its very calm and quiet look, the river is the cause of many deaths every year. Bangladesh, which lies at the confluence of these three major rivers, and the downstream states of eastern Uttar Pradesh, Bihar, West Bengal, Assam and the other northeastern states of India are vulnerable to devastating floods. These are trans-national rivers, so it is difficult for the individual government to implement appropriate and timely measures for forecasting and moderating floods.

The Ganga basin has large supplies of both surface water and groundwater, but faces wide economic water scarcity, especially in Nepal, Bangladesh and eastern India. The average annual flow in the Ganga varies from 5.9 billion cubic metres (BCM) upstream at Tons river to 459 BCM at Farakka barrage. The mean annual input from rainfall to the Ganga basin is 1,179 BCM. The net discharge out of the Ganga is about 429 BCM (37% of input), which is the largest water use (as compared to only 10% for the Indus basin) followed by rainfed agriculture. There is prolific shallow groundwater, but it is poorly developed (about 54%) due to low rural electrification, high prices of diesel fuel and tiny and scattered land holdings (Shah *et al*, 2009). Demographic pressures and industrial development influence the distribution of water between sectors (see Table 1).

Table 1. Water demand in the Ganga basin (to Farakka)

Sectors	Demands (km^3/ year)	% of total demand
Irrigation	93.9	82.1
Domestic	10.7	9.4
Industries	9.8	8.6
Total	114.4	100

Source: Amarasinghe *et al*, 2007

Land and water productivity for most crops and fisheries in the Ganga basin are low and the population dependent on agriculture (> 85%) is very poor (Sharma *et al*, 2010). The Ganga often floods during the monsoon season, and coastal Bangladesh is subject to cyclones, but there are dry spells and even droughts. Groundwater downstream is widely contaminated with arsenic (Chakraborty, 2004). As such, the vast GBM basin population is poor, vulnerable and food-insecure. Poverty in the region is intense, multi-faceted and still a rural phenomenon.

Thus, improving agricultural productivity and income is a major pathway for reducing vulnerability and poverty and improving food security.

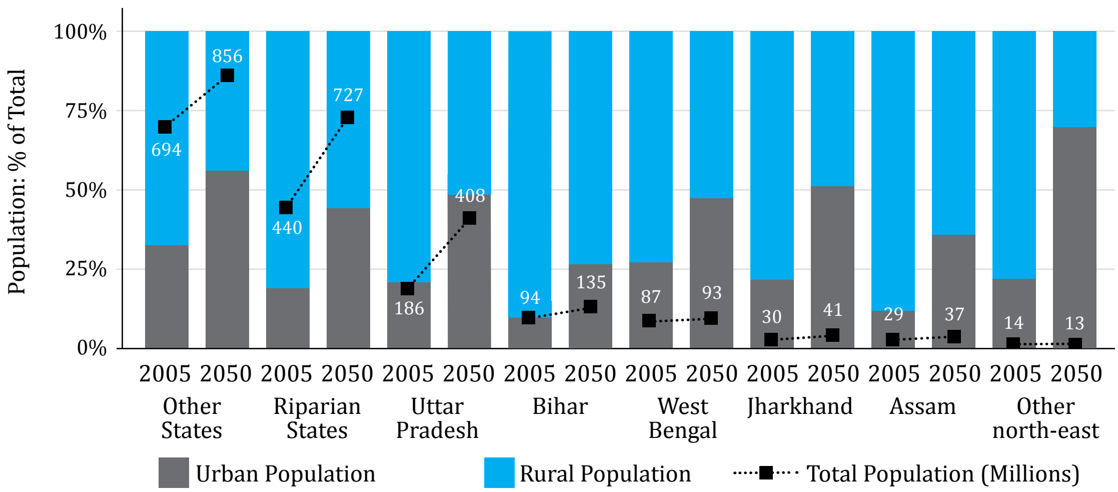
Many factors contribute to low agricultural productivity in the GBM basin. Major constraints are small and fragmented land holdings; inadequate access to energy, road infrastructure and markets; weak institutions to resolve local, regional and trans-boundary issues; low investments in the agriculture and water sectors; and, vulnerability to natural hazards of floods and droughts. Water is abundantly available in the GBM, but access to a reliable water supply is not adequate due to poor socio-economic conditions. To what extent these factors cause or are an effect of poverty are not clearly understood. Clear understandings of the linkages are vital for designing geographically targeted interventions for increasing productivity, ensuring food security, reducing rural poverty and ensuring sustainable water use.

Poverty profile and hotspots

Let us first look at population. The GBM is one of the most populous basins of the world. The riparian states in India contain 39% of the population of India (1,134 million in 2005). The Ganga basin alone contains 91% of the population of the riparian states.

Higher population growth and dense rural population dominates the demographic profile in the riparian states. By 2050, the total population of India is expected to reach 1,583 million, of which the riparian states may share 46% as against 39% in 2005 (see Figure 1). In absolute terms, 287 million more people will live in the region by 2050, increasing the population density by 65%. The

Figure 1: Rural and urban population, 2005, India GBM



Note: 'Other north-east' includes Arunachal Pradesh, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura. Source: Population Census, 2001 overall urban population of India is increasing fast and is likely to surpass rural population by 2030 (Aslam and Kundu, 2009). But rural population in the riparian states will still out-number the urban population by 50 million, even by 2050. Implications of these are increasing pressure on the region's natural resources.

A large part of the rural population depend for their livelihoods on agriculture. Crop, fisheries and milk production are the main agriculture economic activities. As a result, exploitation of natural resources, already overwhelming, is likely to increase and spread to many areas. The riparian states have 59% of India's poor and a major part of those lives in rural areas. Given the high growth of rural population, poverty will still be a rural phenomenon in the riparian states.

Poverty

Poverty is multifaceted. Income, consumption and expenditure-based poverty indicators are widely used for understanding its magnitude and spread. But they do not adequately describe various other dimensions of poverty, which include access to basic needs, livelihood opportunities, infrastructure and assets, information; exposure and resilience to internal and external shocks; and social and gender equality (Cohen, 2009).

This situation analysis looks at the present situation of a few of the above dimensions. The sources of data for this analysis is consumption and expenditure surveys, conducted by the National Sample Survey Organization of India (NSSO), in 1999/2000 (55th round) and 2004/2005 (61st round).

Consumption and expenditure poverty indicators

Three popular measures of poverty[1] based on consumption and expenditure are:

- *Head Count Ratio* (HCR): extent of poverty as a proportion of population below a poverty line;
- *Poverty Gap Index* (PGI): depth or intensity of poverty as average distance of income from the poverty line; and
- *Squared Poverty Gap Index* (SPGI): severity of poverty among the poor as average squared distance of income from the poverty line.

Table 2. Poverty in the India GBM, 2004-05 and 1999-2000

Indicators	61st round in 2004/2005			55th round 1999/2000		
	Riparian States	Other States	India	Riparian States	Other States	India
Head Count Ratio (HCR) (%)	26.9	18.2	21.9	35.3	20.3	26.5
Poverty Gap Index (PGI) (%)	6.4	5.0	5.6	6.0	8.3	6.5
Squared poverty gap index (SPGI) (%)	3.0	3.5	3.3	1.7	2.4	1.9
Distribution of MPCE within 20% of the poverty line (PL)						
1.2 PL > MPCE > 1.1 PL	8.9	7.5	8.1	9.9	7.4	8.4
1.1 PL > MPCE > 1.0 PL	9.5	6.9	8.0	10.4	7.1	8.5
1.0 PL > MPCE > 0.9 PL	9.4	6.1	7.5	10.2	6.2	7.9
0.9 PL > MPCE > 0.8 PL	7.6	5.1	6.2	9.3	5.5	7.1

Source: IWMI calculations

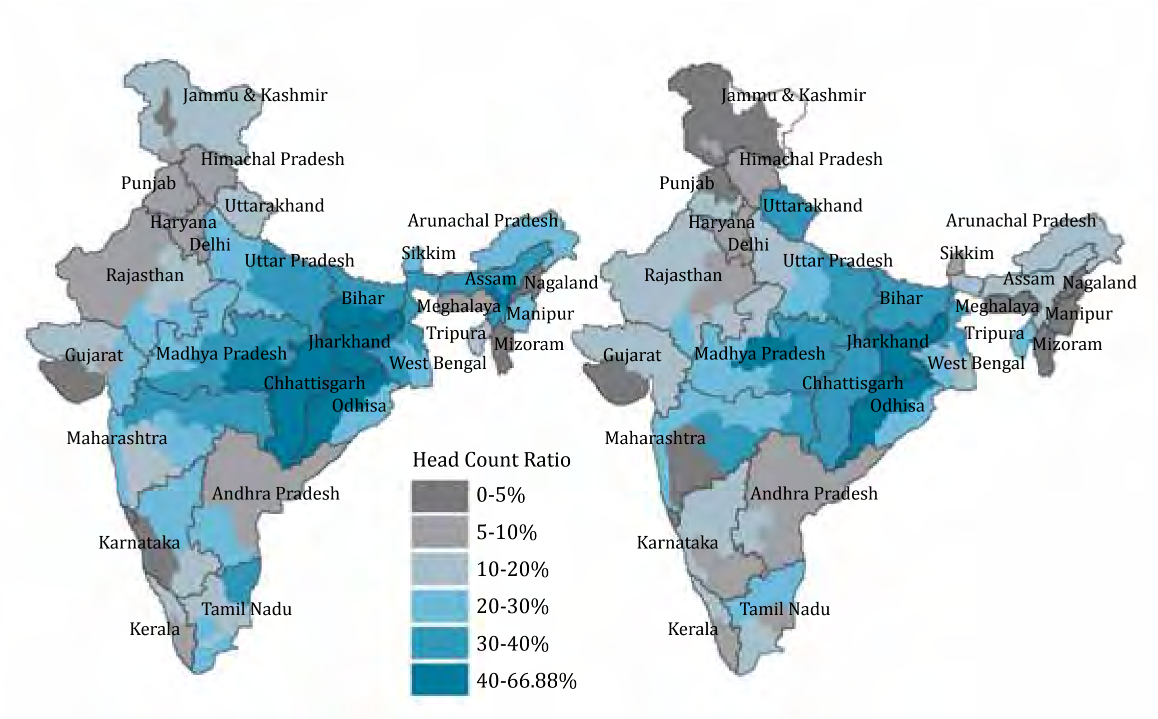
The poverty line is the monthly per capita expenditure (MPCE) on commodities sufficient for providing minimum nutrition needs. While HCR, PGI and SPGI emphasize the count of poor people below the poverty line, the gap between the income of the poor and the poverty line, and the inequalities of income among the poor people, respectively.

Although poverty has decreased considerably between 1999-2000 and 2004-05, the riparian states still have significantly higher HCR compared to other states (see Table 2 and Map 1). Between the 55th and 61st rounds, rural HCR has declined by 24 percent in the riparian states, compared to 10 percent in other states. But Bihar and Jharkhand still have some of the highest HCR among all states (see Map 1). And with higher growth of rural population, the rural poor in the riparian states has in fact increased, from 116 million (36.6% of 317 million total population) in 1999-2000 to 120 million (32.6% of 353 million) in 2004-05.

Likelihood for transient poverty is high in the riparian states. Distribution of MPCE shows a large population has MPCE just above the poverty line (see Table 2). In the riparian states 18% and 17% of the population fall above and below 20% of the poverty line, respectively. As the region is beset with recurrent natural hazards, a substantial part of the non-poor population is also vulnerable to poverty. And any exogenous price shocks in basic commodities could aggravate the situation.

A large part of the rural population is also *chronic poor*. Almost 10% of the rural poor have MPCE below 20% of the poverty line. Many of them are likely to remain poor over the next few years. How well the poor, including the transient and chronic poor, cope with natural hazards and external shocks and improve their livelihoods depend on various other dimensions of poverty.

Map 1: Extent of poverty in India GBM, 1990-2000 and 2004-05



Source: IWMI calculations

Poverty's other dimensions

The MPAT or Multidimensional Poverty Assessment Tool of the International Fund for Agriculture Development (IFAD) is a good entry point to assess other dimensions of rural poverty. MPAT focuses on basic needs, assets and inequalities and requires elaborate surveys and analysis to quantify the levels of different dimensions of poverty. This report only shows present situation, with indicators or proxies of a few dimensions based on the NSSO 61st round (see Table 3).

- ***Education***: Low educational level of heads of households, a major driver of overall poverty, is a common feature across all states. Illiteracy is more prevalent in poor households, although riparian states fare little better in this aspect. Overall only 5% of the heads of poor households in the riparian states have education beyond primary school, whereas more than half of the heads of non-poor households have secondary or higher education. Larger household sizes are also a cause as well as an effect of different dimensions of poverty in all states.
- ***Farm Assets***: Adequate access to farm assets, a major driver to reduce rural poverty, is far from satisfactory in the riparian states. Average land-holding sizes and cultivable command areas of poor households are significantly lower than those of non-poor households. In fact, the average land-holding size per person of poor households in riparian states is only half that of poor households in other states, and only one-sixths of that of the non-poor in riparian states. Distribution of land is significantly skewed towards non-poor in the riparian states (see Map 2, p 14).
- ***Access to irrigation***: A major driver in improving productivity and reducing rural poverty. Although a significant part of the crop area is irrigated, rural poverty is high in the riparian states (see Map 2). Major reasons for high rural poverty are small and scattered land holdings sizes, traditional low-value foodgrain-based cropping patterns and inadequate access to other infrastructure.

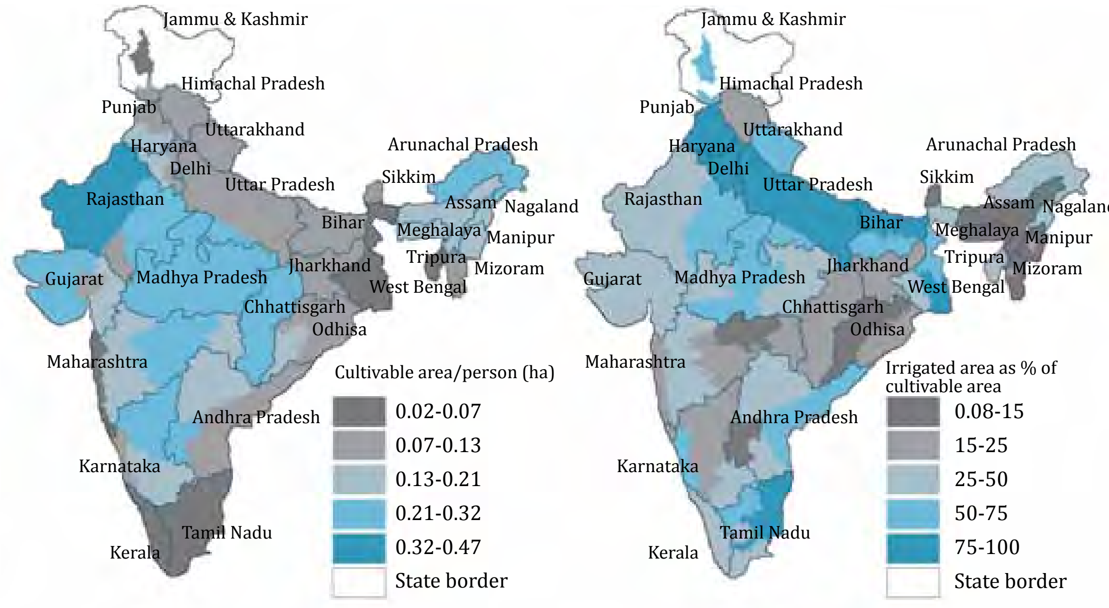
  Groundwater is abundant and now the major source of irrigation in the riparian states. However access to electricity, a vital driver of the groundwater revolution, is generally lower in the riparian states and significantly lower among poor households across all states (see Table 3). In water-abundant eastern India, farmers mostly use diesel pumps, which have become increasingly costly to run, and with different outcomes. The price of diesel fuel increased by 670% between 1990 and 2006, while the farm gate price of rice only about 60%; the trend continues. The squeeze on small-scale irrigation is therefore approaching a crisis, particularly in the eastern India states (Sharma *et al*, 2010).
- ***Non-farm assets***: Non-farm employment and/or regular income earning opportunities often offset inadequate income from farms. However, this aspect is also low among the rural poor. In fact, a substantial part of the rural poor in all riparian states depend their livelihoods on agriculture or other labour.
- ***Social Safety nets***: Distribution of social safety nets is highly inequitable between poor and non-poor households. In the riparian states, more non-poor households have either BPL (Below Poverty Line) or *Antodyaya* (Old age; 10 million poorest among BPL families) ration cards than poor households. And a significantly higher number of non-poor households are beneficiaries of food for work, *ANNAPOORNA* (the poor old people who are not covered under national pension schemes), ICDS (Integrated Child Development Services) or midday meal programs. Clearly, many of the social safety net programs seems to be poorly targeted in the riparian states.
- ***Knowledge gaps***: Natural hazards such as floods are a recurrent phenomenon in the riparian states. These often disrupt the livelihood systems of both the poor and the non-poor, while the plight of the poor worsens. Importantly, a large part of non-poor households at the margin are

Table 3. Multi-dimensional poverty in riparian and other states in India

Indicators	Poor households			Non-poor household		
	Riparian States	Other States	India	Riparian States	Other States	India
1. Education						
• HH head illiterate (%)	41	52	59	20	36	29
• HH head, primary education (%)	54	32	36	29	42	37
• HH head, secondary education (%)	5	4	5	11	15	14
2. HH size (#)	5.7	5.6	5.7	5.2	4.8	4.9
3. Farm assets						
• Own land (%)	84	93	89	96	94	94
• Land size (ha/hh)	0.31	0.59	0.46	1.93	1.19	1.48
• Cultivable land (ha/hh)	0.29	0.56	0.43	0.78	1.06	0.95
• Irrigated land (ha/hh)	0.14	0.10	0.12	0.38	0.51	0.46
• Land size per person	0.05	0.11	0.08	0.36	0.25	0.29
4. Housing and energy						
• Own house						
• Lighting with electricity	24	10	44	27	79	58
5. Non-farm assets						
• Regular salaried HH	19	6	12	33	18	24
• Self-employed non-agriculture HH	21	18	20	24	22	23
• Cultivators HH	24	22	23	42	34	37
• Agriculture labour HH	22	34	29	8	15	12
• Other labour HH	15	17	16	7	12	10
6. Social support/inequalities						
• Ration card type – BPL	29	52	41	27	28	28
• Ration card type - ANTODAYA	22	6	14	29	3	14
• Beneficiary of Food for work	16	20	18	22	7	13
• Beneficiary of ANNAPOORNA	9	2	5	17	1	7
• Beneficiary of ICDS	7	13	10	11	5	8
• Beneficiary of mid-day meals	17	38	28	16	19	18
7. Access to information/transport						
• HH with a radio	21	14	18	32	31	31
• HH with a TV	5	11	8	19	48	37
• HH with a bicycle	48	34	40	38	42	40
• HH with a motorcycle	1	1	1	6	18	13

Note: HH=house hold; Source: Authors' estimates based on NSSO survey 2004-05

Map 2: Land-holding size (per person) and irrigated area (% of cultivated area), India



Source: NSSO 61st round

also vulnerable to poverty. And these households could also benefit from properly targeted safety nets. Safety nets are poorly targeted and can ignore those non-poor at the margin. Development programmes need to be targeted on the basis of the levels of various other dimensions of poverty. Yet, this information in the riparian states is not adequate.

MPAT is a useful starting point for quantification and regular monitoring of many facets of rural poverty. Distribution of even a few of these indicators shows much work needs to be done to properly understand the causes and effects of transient and chronic poverty. Also, indicators in MPAT need to be refined to identify properly targeted poverty alleviation programs for the transient and chronic poor.

Food security

Food security and foodgrains are inseparable in the Indian context, and more so in the riparian states. Foodgrains are the main source of nutritional supply of the Indian diet, directly accounting for 65% of the daily calorie intake (see Table 4). Dry-fodder and feed grains are important inputs for production of milk and meat. And indirectly, foodgrains through consumption of animal products contribute to a further 8% of the daily calorie supply. In the riparian states, foodgrains and animal products account for 75% of the daily calorie intake.

Food security generally means adequate supply of food to meet the minimum nutritional requirement of all people at all times. In this context, and also to protect the large poor and non-poor population alike from large price fluctuations, self sufficiency of foodgrains is a priority in India. However, although the country as a whole is self-sufficient in foodgrains, a large population still lacks access to adequate food to meet its minimum nutritional requirement. The major concerns in food insecurity of the poor households arise in food distribution and access. This is largely achieved through a highly inefficient Public Distribution System and food subsidies system. This essay does not assess issues related to food distribution at the household level. Rather it assesses the food production surplus or deficits as a proportion of total consumption to explore the food insecurity situation at the state level.

Rice and wheat are the major foodgrains, accounting for 89 percent of the total consumption in the riparian states, compared to 69 percent in the other states. Overall production of rice and wheat in the region exceed the demand, due mainly to surplus production in Uttar Pradesh (see Map 3, p 16). In fact, Uttar Pradesh, West Bengal and Chhattisgarh, Punjab and Haryana are the only states which have recorded substantial production surpluses of rice and wheat, amounting to 173% and 81%, respectively, of total consumption. These surpluses are more than adequate to offset the production deficit of other food-deficit states, which includes all other riparian and non-riparian states (except for West Bengal, Andhra Pradesh, Tamil Nadu and Tripura, which are rice surplus states).

However, rice and wheat production surpluses in Haryana, Punjab and western Uttar Pradesh are maintained with a high level of groundwater irrigation (see Map 3, p 16). Current pace of groundwater pumping in these areas is not sustainable. Sustainable agriculture production requires a major reduction in groundwater depletion. In many areas this is only possible by reducing the rice area. Such a strategy obviously will reduce overall rice surpluses of the three states. Therefore, many of the relatively water-abundant riparian states, with low land and water productivity, need to increase rice production to assure food security for the riparian as well as other states (Sharma et al., 2010) . Two factors—small land-holding size and access to irrigation—will determine the extent to which this can be done in the riparian states.

Low-value agriculture in small land-holdings is a major constraint in reducing vulnerability and poverty. This will exacerbate with increasing rural population. Agricultural diversification is a

Table 4. Self-sufficiency of foodgrains in GBM riparian and other states, India

	Riparian States	Other States	India
Daily calorie supply (kcal/pc/day)	2413	2465	2444
• % calorie supply from food grains	69	62	65
• % calorie supply from non-grain food	25	30	28
• % calorie supply from animal products	6	9	8
Food consumption per person (kg/year)			
• Food grains	202	195	198
• Rice	90	77	82
• Wheat	76	58	65
Production surplus/deficit-% of consumption			
• Food grains	-(4.5)	4.7	1.0
• Rice	5.2	5.6	5.4
• Wheat	1.4	13.6	8.0

Source: Authors' estimates based on 2000 agriculture production data necessity to bring many rural people out of poverty. *How and where this can be done, while ensuring adequate foodgrain production, requires further study.*

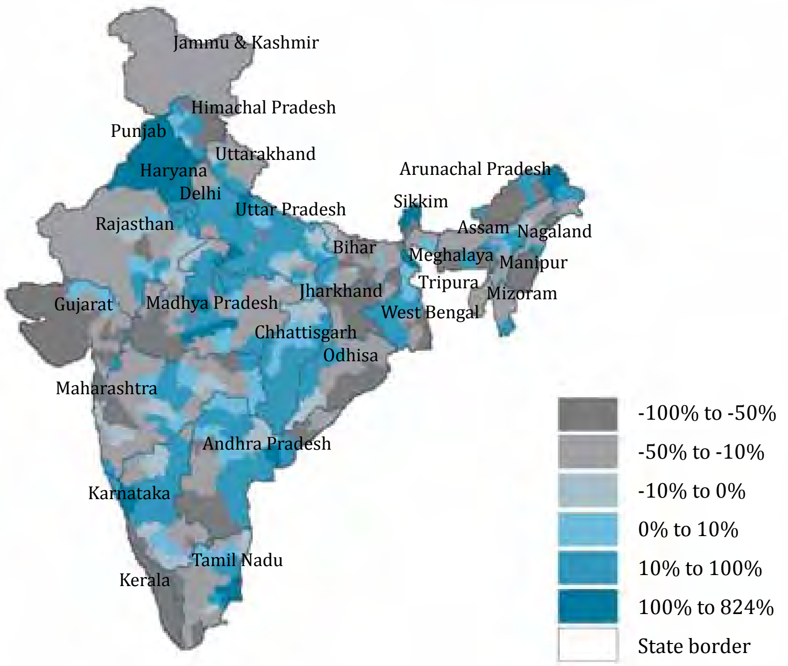
Increasing foodgrain production requires major increases in crop yields. Theoretically, that increases crop transpiration and so may require irrigation in many places. How far crop yields can increase without a major increase in crop-consumptive water use needs further study. This is especially important given the increasing cost of investments in developing water resources for irrigation and increasing competition for water from other sectors.

Environmental hotspots and vulnerability

The foodgrains self-sufficiency in India has been achieved at a significant environmental cost. Many foodgrain production surplus areas, including Punjab, Haryana and western Uttar Pradesh, have severe groundwater over-exploitation. Groundwater is the source of irrigation for 60% of the irrigated area in India. This share is as high as 90% in western Uttar Pradesh. As a result, consumptive water use (CWU) from groundwater for crops, in many regions, exceeds natural recharge (see Map 4).

Rice production shares a large part of groundwater CWU. Sustainable agriculture production in many regions is possible only by reducing the rice area. The abundant groundwater resources in the eastern region are expected to contribute to offset production losses due to over-exploitation of water resources in the north-west.

Map 3: Foodgrain production surplus/deficits (% of total consumption), India



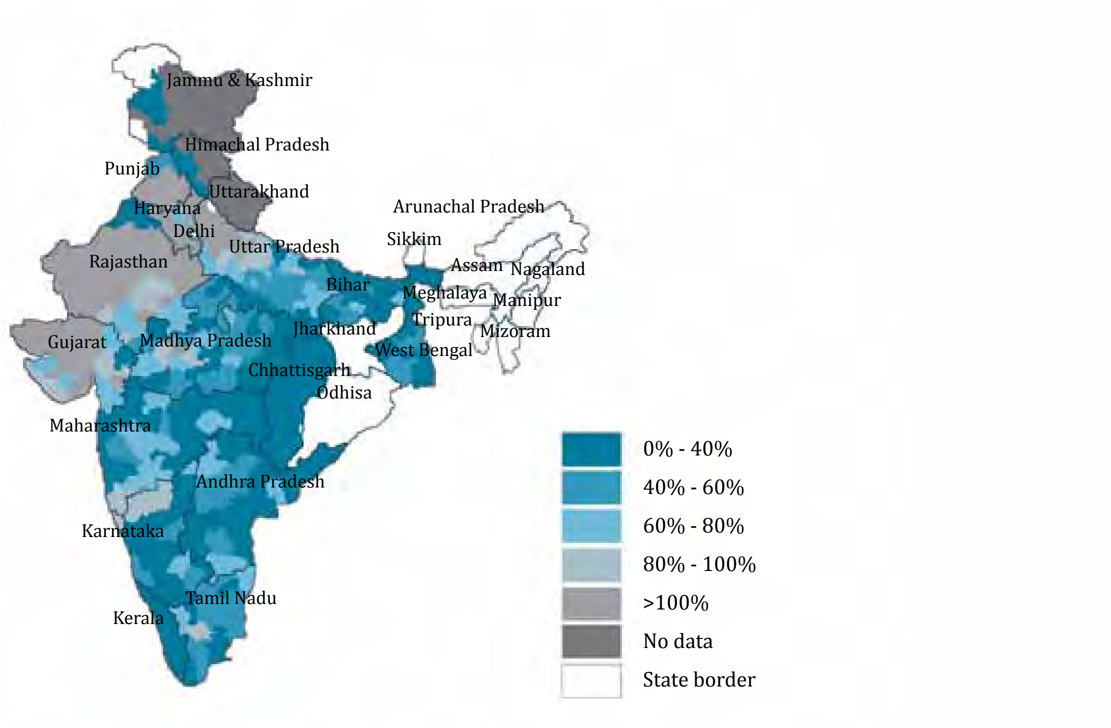
Source: Authors' estimates based on 1999-2000 production and consumption of foodgrains

Although groundwater is abundant, the eastern region has other types of environmental problems. The groundwater is contaminated with arsenic in the GBM basin. The source of arsenic in this region is the Himalaya and the Tibet Plateau, and hence the flood plains of all the rivers that originate from those sources are expected to be arsenic-contaminated. Ganga, the major river in North India flows through five states in India, and four of them are arsenic-contaminated, especially Bihar and West Bengal in India and large parts of Bangladesh (Chakraborty *et al*, 2008).

Floods are a recurrent phenomenon in the GBM basin and large parts are flood-prone in eastern Uttar Pradesh and Bihar. Flood is a regular annual phenomenon in this area while severe floods cause damage to life and livelihood resources and have adverse consequences for the development of the area (Ahmed and Ahmed, 2003). In the context of climate change, the frequency and intensity of floods are likely to be enhanced.

Very high and intense rains in the adjoining steep Nepal hills dump large amounts of runoff in the nearly-full flowing Ganga, causing huge overflows and floods in the eastern plains. The flood-prone area of the Ganga spans across and mainly covers the Nepal terai, eastern Uttar Pradesh, Bihar and West Bengal in India, a part of the north-west and the whole of southwest region of Bangladesh (see Map 5, p 19). The most probable period of flood is July-September, during the *kharif* season, one of the major cropping seasons in the area. Devastating floods are also observed in the Brahmaputra basin, with the plains of Assam witnessing heavy livelihood and economic losses on a regular basis. The average annual losses due to floods and heavy rains in India, 1953-2002, are astronomical and

Map 4: Groundwater CWU in India (% of net recharge)



Note: CWU = consumptive water use; Source: Amarasinghe *et al*, 2011 provide a picture of the effect of floods (see Table 5). Recurrent floods are also one of the main reasons for continued and high poverty in the GBM basin.

Due to the physical and hydrological setting, flood-prone areas cannot be fully protected. But they can be adequately managed. To minimize the risk of people living in the floodplains in this area, combination of structural and non-structural measures should be implemented. Structural measures include construction of embankments and polders while non-structural measures include flood proofing, flood warning, flood zoning and community participation in flood management. Regional cooperation among the basin countries would highly enhance the flood forecasting and warning, flood protection and flood management capabilities of individual countries. Such cooperation could be on structural and non-structural aspects of flood management.

Water productivity

Increasing water productivity (WP) is a better strategy when water is scarce and/or becomes costly. That means producing more crop per drop (physical WP) or value per drop (economic WP) of water use. Physical or economic WP are defined as the ratio of production (in kg/cu m) or value of outputs (in US $/cu m) to consumptive water use (CWU). The CWU of crop production is the reference evapotranspiration from the crop area during the crop growth periods (initial, development, mid- and late stage).

Foodgrains are not only a vital component of food security but also of rural livelihoods. In the GBM basin in India, foodgrains alone occupy 84 percent of the annual cropped area. Therefore, the main focus of the physical WP analysis in this report is on foodgrains (rice, wheat, maize, sorghum, barley, *bajra* or pearl millet, *ragi* or finger millet and small millets and pulses). Rice and wheat have the largest share, comprising 82% of the foodgrains area. Maize and pulses contain another 4% and 10%, respectively, of the area.

Increasing yield may increase physical WP. But due to small land holdings, increasing productivity of foodgrains alone may not be sufficient to reduce poverty in the riparian states. Since agriculture is the main livelihood for many rural people, the report also assesses economic WP in terms of overall value of agricultural output. This includes the value of output of foodgrains, oil crops, fruits, vegetables (including roots), sugarcane, cotton and fodder crops and milk.

Foodgrains water productivity

The average physical WP of foodgrains in the riparian states is only slightly lower than those of other states (see Figure 2, p 20). The physical WP of rice, wheat and maize in the riparian states are 0.39, 0.93 and 0.28 kg/cu m, respectively. Comparable estimates for the other states are 0.45, 1.02, and 0.41 kg/cu m. However, physical water productivity of foodgrains is much higher in Punjab and Haryana.

Rainfall has the least opportunity cost of any agriculture water supply. It is the main source of CWU for foodgrain production in the riparian States (see Figure 2, p 20). This is true for all crops except wheat. And being a winter (dry season) crop, wheat production is not possible without irrigation in the northern regions. The rainfall and irrigation CWU components are often generally called green and blue water footprints of crop production (Hoekstra, 2003).

Rainfall contributes to 80% of the total CWU of rice (2,538 cu m/tonne) in the riparian states as against 57% of the total CWU (2,234 cu m/tonne) in the other states. In contrast, rainfall contribution can be as low as 30% in Punjab with a total CWU of only 1,782 cu m/tonne. The differences in CWU are mainly due to rice yield. In Punjab, average rice yields—4 t/ha—are more than two times that in the riparian states. This indicates there is a significant scope to increase rice yields in the riparian states without additional CWU.

Physical WP of foodgrains varies significantly across districts and states (see Map 6, p 21). Thanks to high yield, Punjab and Haryana have the largest foodgrain WP. Generally, rainfed production areas have low physical productivity. This is either due to low yields or high CWU/ha or both. Much of the riparian states have low foodgrains yield and high CWU. Other factors such as crop combinations could also affect physical WP of foodgrains. An area with wheat as the only foodgrains crop grown can have higher physical WP than in an area where a combination of foodgrains crops is grown.

Analysis of physical WP across states shows that an increase of 1% rice yield can increase WP

Map 5: Flood-prone areas in the Gangetic basin

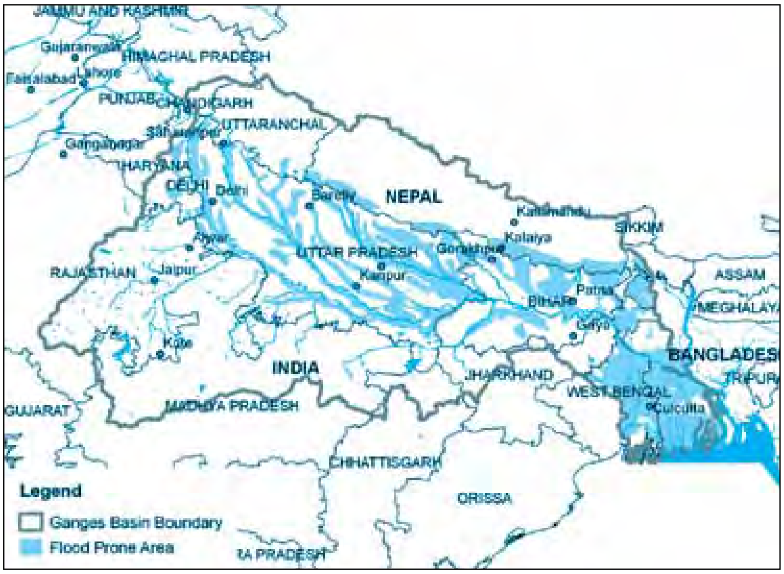


Table 5: Damages due to floods/heavy rains, India, 1953-2002

Item	Damages
Population affected (million)	32.980
Human lives lost (no.)	1560.000
Cattle lost (no.)	92791.000
Geographical area affected (million ha)	7.378
Cropped area affected (million ha)	3.474
Value of damaged crops (million US$)	132.700
Damage to houses (million US$)	40.020
Damage to public utilities (million US$)	125.820
Total damages (Crops, houses, utilities) (million US$)	300.510

Source: BFP-IGB toolkit, IWMI, Colombo

or decrease CWU by 0.57% [ln (WP)= 5.8 +0.57 ln(yield), R^2=51%]. Since the opportunity cost of effective rainfall is very low and rainfall is the main source of water supply, the riparian states have ample opportunities to increase rice production where land is available. A similar situation exists for maize and pulses, where the contribution of rainfall CWU is even more in the riparian states.

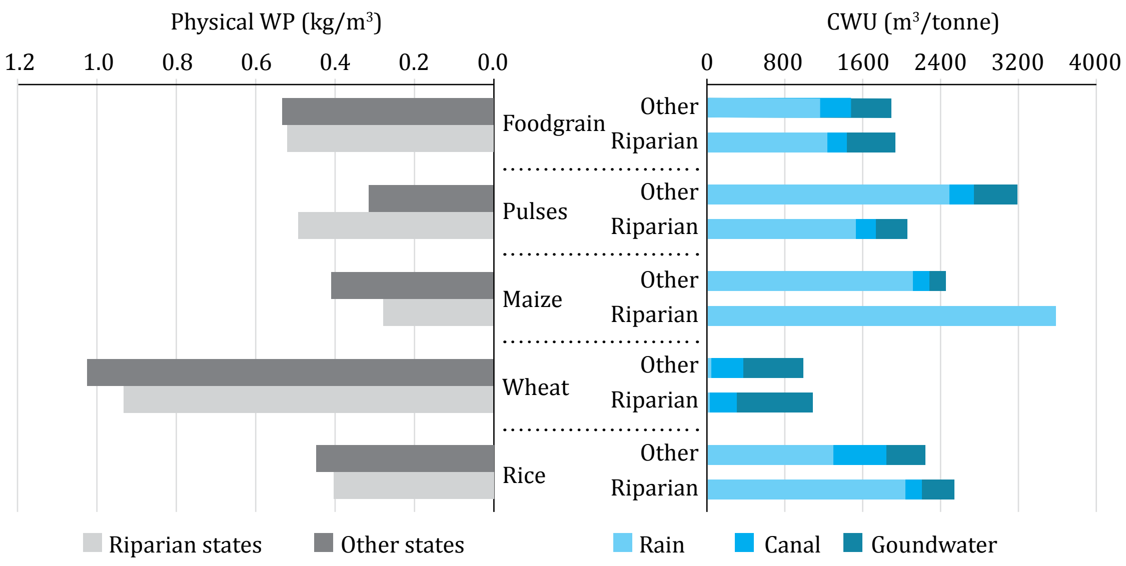
However, is increasing yield of foodgrains alone adequate for reducing poverty in the riparian region? Not necessarily, if the variation of foodgrain physical WP and rural HCR across states is considered (see Figure 3, p 22). The states are ordered according to the rural HCR; Bihar has the largest HCR. The physical WP foodgrains in Bihar is similar to that of Gujarat, but Bihar has almost three times more HCR. The WP of foodgrains in Uttar Pradesh is similar to that of Rajasthan, but incidence of rural poverty is about two times higher in Uttar Pradesh. West Bengal has physical WP similar to that Andhra Pradesh, but has three times more rural HCR. The WP of foodgrains of some of the northeastern states is also low, but they have low poverty too.

Thus, increasing physical productivity of foodgrains alone is not sufficient to reduce poverty in the riparian states, and many other factors constrain rural poverty alleviation. First, foodgrains are generally low value crops. Without a major increase in marginal WP, such as in Punjab or Haryana, improvements of physical water productivity cannot make a significant dent in the rural poverty of households with small land-holdings. Second, riparian states have a large number of small land-holding and high rural population. For small land-holdings, an alternative and a better strategy is to increase economic water productivity.

Economic water productivity

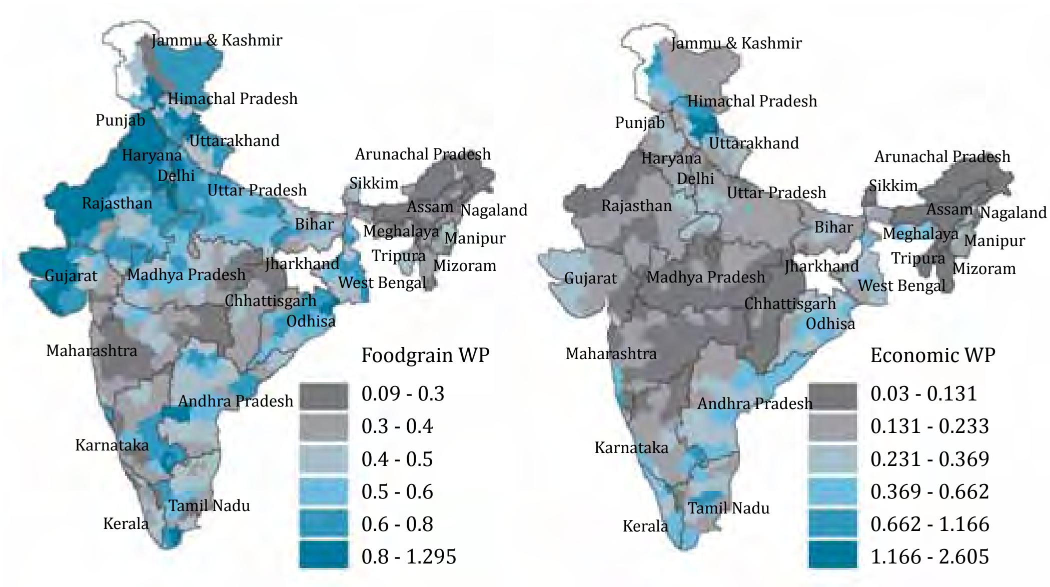
Interestingly though, the economic WP of crops and milk production in Uttar Pradesh, Bihar and West Bengal are either fairly similar or higher than those of Rajasthan, Gujarat or Andhra Pradesh (see

Figure 2: Physical WP (kg/m^3) and sources of CWU of foodgrains (m^3/tonne), India



Note: WP=Water Productivity; CWU=Consumptive water use. Source: Amarasinghe *et al*, 2011

Map 6: Foodgrain WP (kg/m^3) and economic WP (US$/m^3) in India



Note: WP=Water Productivity. Source: Authors' estimates based on 2003-04 crop and milk production data

Figure 3, p 22). This shows higher economic WP does not necessarily guarantee low poverty, either.

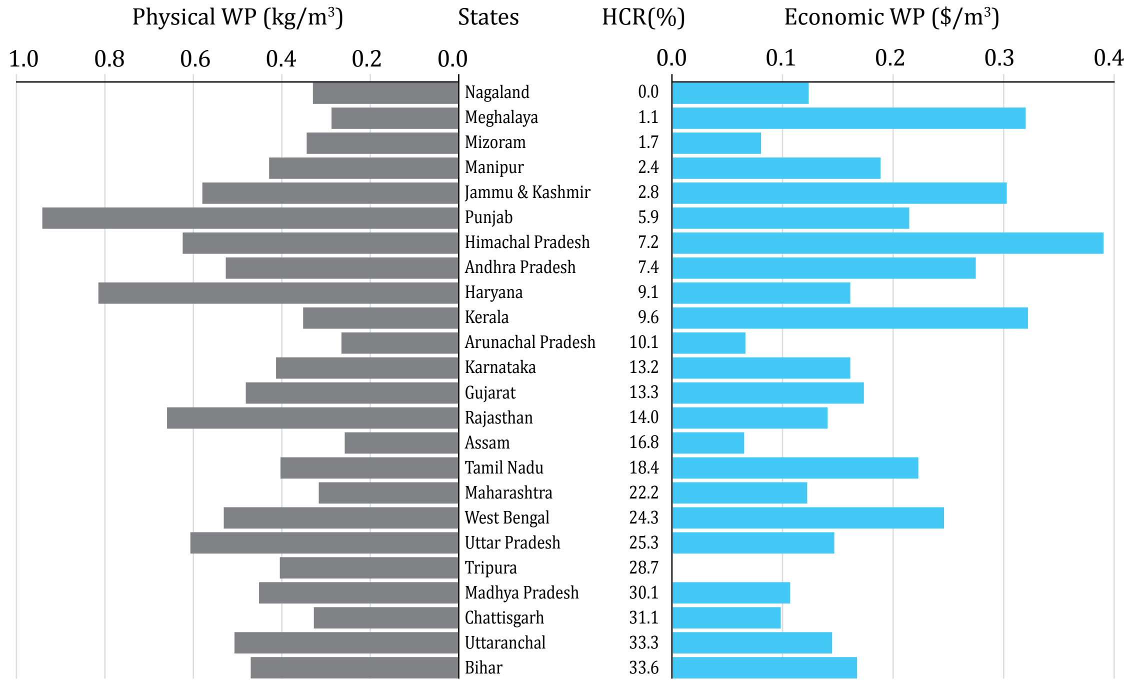
In fact the sizes of the land-holdings, the economic activities that generate the outputs and the rural population that depend on them are key determinants of rural poverty. shows the variation of value of agriculture output per unit of net sown area and per rural person across states (see Figure 4, p 23). The riparian states with large HCR have relatively lower output per person of rural population than those of many of the low poverty states such as Andhra Pradesh, Gujarat and Rajasthan (see Figure 4, p 23). The strategy adopted by the latter states seems to be to increase the overall output per unit land. Along with lower rural population active in agriculture, some non-riparian states have reduced rural poverty much faster. However, many of these states are also facing severe groundwater depletion. And they need rethinking their strategy in the near future. In fact, there is evidence some southern states have already started using precious irrigation water for high-value crops. Fruits and vegetable and milk production are increasing in these states.

What are the options?

So, what options are available for the riparian states? Obviously, a significant scope exists for increasing foodgrain yields and production across the region. But the overall strategy should also include faster poverty alleviation and sustainable water use in river basins. The following interventions may be considered:

- Many regions in the riparian states, especially in the western parts of the country, should reduce the area of high water-consuming crops for sustainable water use and agricultural production. For instance, less rice production and more milk production could ensure both higher income and sustainable water use. This would increase economic WP for the region (Amarasinghe *et al*, 2011).

Figure 3: Physical WP of foodgrains, HCR and economic WP, India



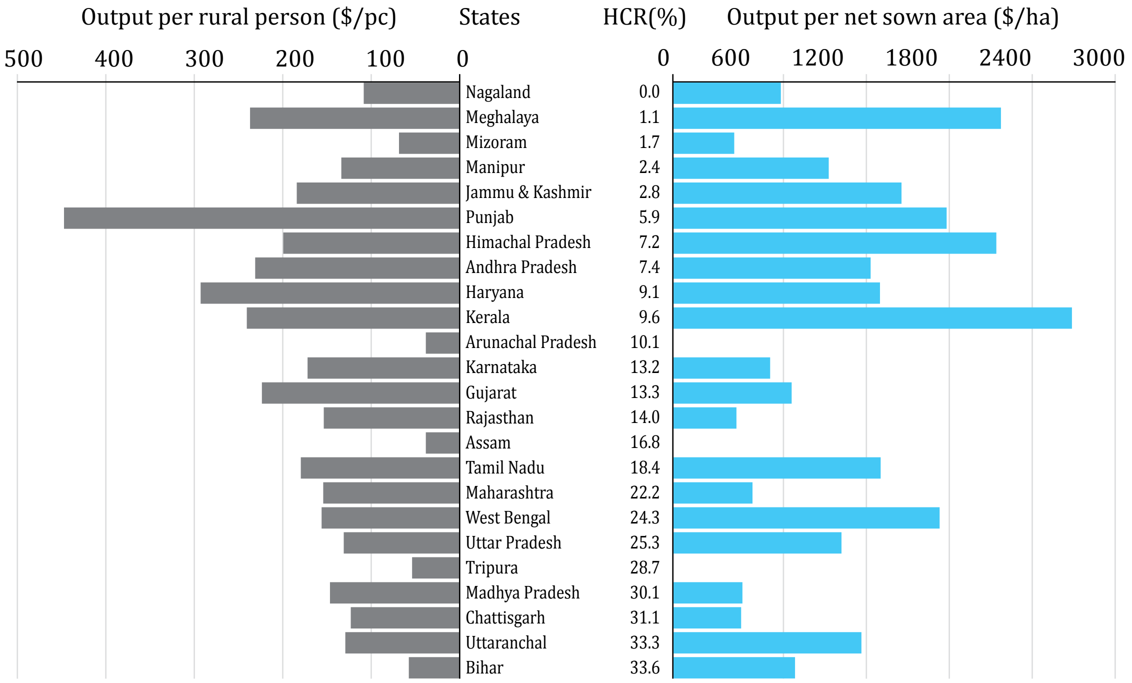
Note: WP=Water productivity; HCR=Head Count Ratio.
Source: Authors' estimates based on 2003-04 crop and milk production data

But the production losses of foodgrains have to be offset from increased production from other regions in the east and elsewhere.

- Due to soil and climatic factors, some location could only grow foodgrains in the wet and dry seasons. Regardless of the land-holding sizes, these areas should increase foodgrains yields and production. Proper management of low opportunity cost rainfall with irrigation water productivity, too, needs to be seriously considered. Additionally, agricultural diversification with animal husbandry, especially milk production, can increase the economic WP and ensure faster poverty alleviation. Proper inclusion of fisheries in the farming systems for high-rainfall and water-congested areas has the potential to improve both the nutrition and economic WP in the region. Innovative and integrated multiple-use farming systems with crops, horticulture, vegetables, livestock and fisheries have a good potential for the eastern and north-eastern region (Sharma *et al*, 2010).
- Soil and climatic conditions in some locations could be conducive for crop and agriculture diversification throughout the year. While small landholders can increase economic WP and income through crop or agriculture diversification, others could strive to increase physical WP of foodgrains with a view to increase food security for the region.

Depending on the location, above interventions will alter the water use patterns and water availability for other uses in a river basin. *Where and to what extent these interventions fit within the basin context, and what opportunities and constraints exist for better adoption by farmers in different localities and for sustainable productivity growth, require further research.*

Figure 4: Value of crop and milk output per rural person and per net sown area, India



Source: Authors' estimates based on 2003-04 crop and milk production data

Conclusion

The riparian states of the GBM basin are full of both distress and promise. Rural poverty is rampant. But opportunities for increasing income and decreasing poverty, perhaps through a green revolution of a different kind, are large. This requires increasing productivity of water use.

In the western regions, irrigation/groundwater development coupled with other components of Green Revolution technology was the major driver behind physical productivity growth. But overexploitation of the resources is constraining further growth. Reducing the depletion of groundwater, while increasing economic productivity, is the best strategy there. Agricultural diversification is the best pathway to increase economic productivity. Where and how this can be done, while ensuring food and livelihood security for smallholder farmers, requires further research.

In the eastern region groundwater is plenty, but use is relatively low due to high energy costs (mainly diesel) and small holdings. A large scope exists to improve physical productivity of crops. Water availability is not a constraint in the eastern region. However, foodgrains are the major crops grown by large number of small holders. Increase in physical productivity alone may not be adequate to get the poor smallholders out of poverty. They also need to increase economic productivity and that requires large-scale agricultural diversification. Understanding the cost and benefits of this requires location-specific studies of inputs, outputs and impacts of various production systems.

Water is only one, but critical, factor contributing to physical and economic productivity growth. But the nexus with energy, infrastructure, markets, support prices and subsidies, development policies and their target regions and populations could be much deeper in various production systems. Sustainable water use for agriculture requires the development and validation of agro-ecology specific integrated farming systems which can generate good revenues for millions of small and vulnerable farming families and also withstand the environmental distresses of recurrent floods and occasional droughts. Unfortunately, there is a serious gap in the available knowledge on water resources development and management; socio-economic constraints and agricultural intensification appropriate to develop the sustainable water use and viable production systems for the GBM basin. Well designed and implemented research to address these research and development questions shall have large impacts for the vast poor populations inhabiting the region and sustainable development and use of the natural resources of the basin.

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Endnotes

1 Foster, Greer and Thorbecke (1984) suggest general index indicating three possible measures HCR, PGI and SPGI. These are given by $P = 1/N\Sigma((L - x_i)/L)^r \, I_{[x_i<L]}$, L is the national poverty line, X is the per capita expenditure, and $I_{[x<L]}$ is the indicator function taking value 1 if X<L, and 0 if X>L. Indicator P for r=0, 1, and 2, I gives the HCR, PGI and SPGI respectively.

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WATER, FOOD SECURITY, POVERTY | INDIA

The dynamics in Indian states flanking Bangladesh

K Vijaya Lakshmi, Vrinda Chopra and Kriti Nagrath

Thousands of years of civilisation have flourished in the GBM river system, which determines the lives of a large trans-boundary population even today. The GBM river system carries over 2.9 billion tonnes sediments (one third of global sediment transport to the world's oceans) into the Bay of Bengal. These sediments transform the landscape into one of the most fertile lands of the world. About 18 km of sediment, thus deposited in the sinking basin, make it the world's deepest sedimentary basin (Patkar, 2004).

The GBM river system has one of the highest run-off rates in South Asia, with annual water flow averaging at about 1,350 billion cubic metre (BCM), while the replenishable reserve of groundwater is 230 BCM in the region (Ahmad *et al*, 2001). Of the average rainfall, 80% occurs June-October. Of the total flow of water in the system, an average 1,160 BCM (85%) is available, after losses due to evaporation, evapotranspiration and deep percolation, for use in Bangladesh or passes into the Bay of Bengal (Ahmad *et al*, 2004). Almost the entire flow, water and sediment, of the GBM river system passes into the Bay of Bengal through Bangladesh, often causing serious environmental damage.

In the 1960s, rapid expansion of water development projects was guided by the priority of food security of the newly independent nations. This was closely followed by the development of hydropower projects. The more informal but political role of large projects in the redistribution of river waters should, however, not be underestimated. The Himalayan rivers, especially those providing snow and ice-melt flows, became increasingly important as sources of water for the plains during the lean period (Bandopadhyay and Ghosh, 2009). Even today, water is primarily managed through an engineering perspective rather than an ecological one, with a focus on large projects.

The high level of precipitation, annual run-off, and a large hydroelectric potential of more than 1,00,000 MW have been seen as enabling factors for economic development and poverty eradication in the basin (Verghese, 1990). Populations in Bangladesh, India, and Nepal are growing rapidly each year (see Table 1). But other social indicators like literacy, infant and child mortality are lower than the world's average. Access to safe water has increased, but sanitation remains woefully inadequate. Even the per capita availability of arable land is very low, about one tenth of a hectare. The existing urbanization rates are also low, but likely to rise significantly in India and Bangladesh. Thus the basin remains an exception to the traditional understanding which relates poverty to water scarcity (UNEP, 2008); it is one of the poorest regions of the world, with about 250 million people surviving on less than US $2 per day (Ahmad *et al*, 2001).

Many studies and syntheses of information have demonstrated that trans-boundary cooperation in integrated water management in the GBM region can offer these countries benefits far beyond what can be achieved through isolated national efforts (Revenga *et al*, 1998; UNEP, 2004), especially in view of the catastrophic floods the lower basin faces. Today, the challenges faced by the GBM region for water management include: increased pressure on water resources from a growing population and water pollution; greater vulnerability to climate change, especially since the monsoon is expected to get more severe, with increased unpredictability; reduced dry-season flows; increased intensity and frequency of water-related hazards; sea level rise and salt-intrusion. Countries acting alone cannot effectively address these risks (Ahmad, 2010).

The abundance of water available in the basin can be seen as a shared resource which could be a principal driver of development for the millions of poor people living in the region. Properly harnessed, water could be the most important factor for development (Biswas, 2008). Tempering the joint effects of spatial and temporal disparities, dealing with the problems of water use for poverty alleviation and promotion of well-being are the basic challenges for collaborative water management in the basin (Bandyopadhyay and Ghosh, 2009).

In this context, the study focuses on the impact of trans-boundary water issues on food security and poverty concerns in the five states in the GBM basin that flank Bangladesh: West Bengal, Assam, Mizoram, Meghalaya and Tripura. The study first introduces the study area and the overarching problems associated with trans-boundary water regimes. It then highlights the core issues afflicting the region, both in terms of the ecology and socio-economic development. Further, it analyses the interrelations between these identified issues and their impact. Finally, the study points toward future research needs to create a better understanding of these trans-boundary concerns and works towards collaborative solutions.

Table 1 : The GBM basin in India

Basin Parameters	Drainage Area (1000 sq km)	Arable Land (million ha)	Population (millions)
Ganges	861	60.2	370
Brahmaputra	195	5.5	31
Meghna	49	1.5	7
GBM (Total)	1105	67.2	408

Source: Mahbub ul Haq, 1999

Ecological issues

Problems of development in the five Indian states flanking Bangladesh in the GBM region are aggravated due to its physical vulnerability. Many of these are anthropogenic in nature, further complicated by climate change—particularly, freak weather events. This section will therefore take up ecological issues in the area such as floods, groundwater contamination and land use change.

Let us begin with floods and water management. Floods are characteristic of the study area. West Bengal and Assam are particularly prone (see Map 1, p 30) West Bengal, in addition, is susceptible to damage from cyclones arising in the Bay of Bengal. Monsoon precipitations that occur between mid-June to mid-September are the basis for various types of floods in the diverse regions of the basin. In spite of over 3 million irrigation tubewells dug over the past 50 years, the basin still faces some of the most acute problems of waterlogging and flood-proneness. The lower regions of the basin regularly have to deal with high flows in the rivers that drain the intense monsoon precipitations (Bandyopadhyay and Ghosh, 2009).

Beside heavy rainfall, a major concern is the reduced capacity of the river channel to contain the flood flow. Rivers in the GBM basin annually transport 2 x 10^9 tonnes of sediment (Breit *et al*, 2003). The high sediment load significantly reduces the carrying capacity of the channels. The tidal reach and delta areas face widespread inundation when high floods in the river synchronise with high tidal levels from the sea. The plains of West Bengal are affected by spills from either the Ganga or the tributaries. The condition is worsened when the floods in the Ganga and its tributaries synchronise. During June-September, the monsoon, is a critical time for the study area as both major rivers attain their peak discharge (Bandopadhyay and Ghosh, 2009).

Floods in the northeastern states of Assam, Tripura and Manipur along with river bank erosion and sand deposition have significantly affected people's lives and livelihoods as well as the economy of these states. In September 2004 alone floods in Assam, considered the worst in 50 years, destroyed crops worth Rs 990 crore (Patowary, 2004). Impoverishment is a consequence of the intensity of the disasters, of traditional techniques becoming irrelevant and of their inability to adapt these to the changed situation. As a result, people's resilience has declined and they have become more vulnerable to negative impact than in the past (Bharali Neog, 2007).

Let us understand this aspect. Annual floods have always been a part of life in Assam. Though rainfall here is mainly from the southwest monsoons, the harvest festival is in January, the month in which most regions that depend on the northeast monsoons celebrate it. In Assam, traditionally the farmer sowed the first crop before the first floods and reaped what remained of the first transplantation. He transplanted again after the floods, using the silt that came with the floods. The soil nutrients in the silt improved soil fertility. As a result, the main harvest Bihu was in January. There was thus resilience in the tradition of the Assamese and of most other communities. They had developed their culture and tradition according to this annual event.

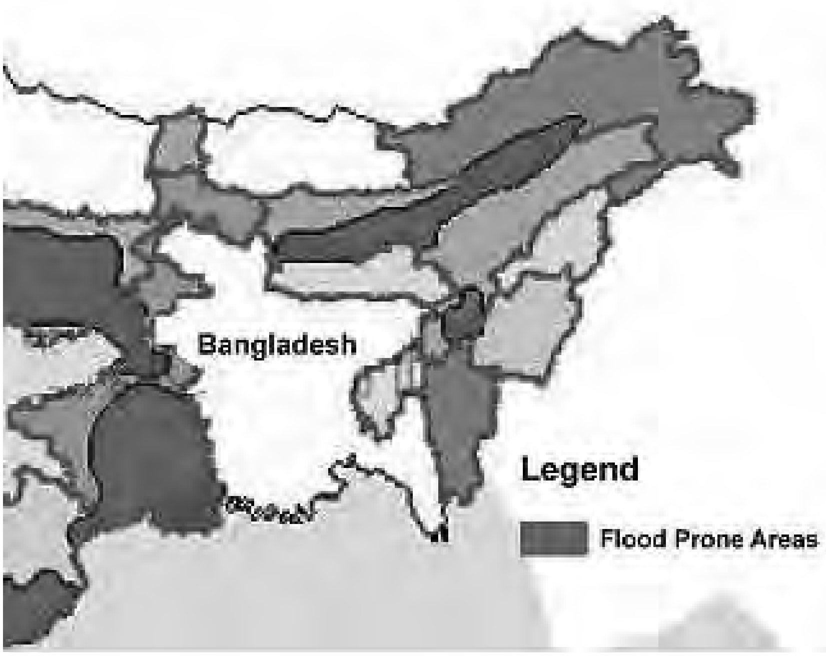
Today floods have become more intense and widespread. Soil erosion does not always allow a second crop after the floods: in 2007, for example, it came in three cycles, the last being in September when the farmer traditionally completed transplantation. Due to the increased intensity and duration of the floods, the farmers can no longer follow the traditional sowing pattern. This has reduced their resilience and increased their vulnerability. Food security is affected, too (Fernandes, not dated).

The traditional perspective of engineering views floods as sources of unmixed damage and loss. However, in the holistic perspective of ecological engineering, monsoon flows also provide important ecosystem services that should get recognized (Bandopadhayay and Ghosh, 2009). Hydroelectricity projects are seen as a win-win option in order to mitigate damage floods cause. More than 168 public and private large river hydropower-dam projects with a cumulative capacity of over 63,000 MW are being planned for the region. These dams promise plentiful power for the nation, economic benefits to states through power export to other parts of the country, flood control and small displacement of local communities. But a careful perusal of the ground situation indicates that displacement is grossly underestimated (Vagholkar, 2007).

With ownership of natural resources lying mainly with communities in most states in the region, state control over resources has remained a source of disgruntlement for many communities. Moreover, the prevailing approach to developing and utilising natural resources without much regard to participation of communities or traditional institutions in the decision-making process has been a source of dissatisfaction for the indigenous communities of the region (Vagholkar, 2007). The present development paradigm coupled with disregard of traditional institutions and community opinion has prepared the ground on which seeds of conflicts have germinated. The nature of water-related conflicts in the region reflect its environmental characteristics, socio-cultural complexity and political sensitivity.

Right from adopting short-term measures like embankments for flood mitigation, lack of proper and culturally acceptable rehabilitation and resettlement packages to inadequate efforts to save riparian areas from collapsing into the rivers, it has been a story of poor governance and inefficient management of flood mitigation. The upstream-downstream interactions within the region and with respect to the contiguous Himalayan areas are also contributing to the conflict scenario. Breaching or unwarranted release of water to rivers from upstream landslide dams have caused catastrophic floods in downstream areas in Assam. Lack of coordination and cooperation between countries

Map 1: Flood prone areas in the Indian sub-region flanking Bangladesh



Source: Adapted from Das, S. K., Gupta, R. K. and Varma, H. K. (2007), 'Flood and drought management through water resources development in India', in *Bulletin*, World Meteorological Organistion sharing the river basins is a major obstacle in resolving these problems.

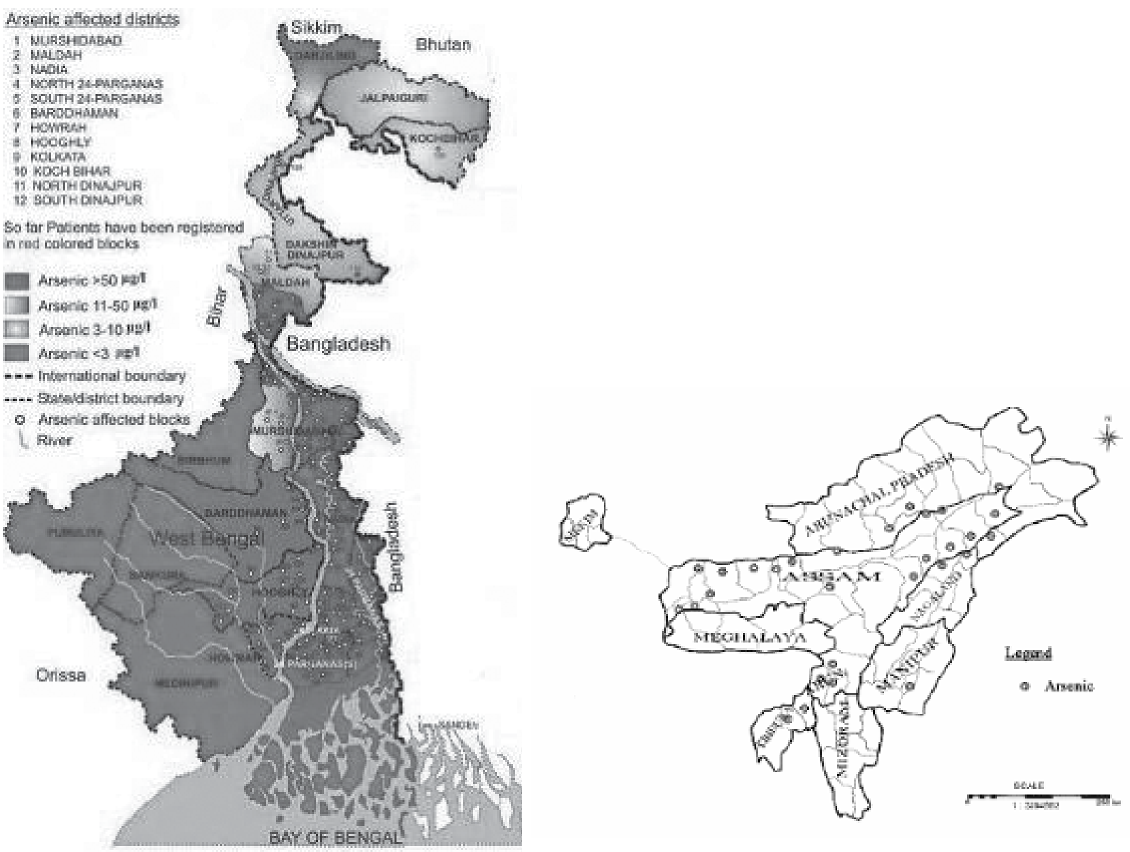
Water-resources management in all the co-riparian countries is fragmented among many agencies and needs to be integrated. Exchange of meteorological and hydrological data and information among the riparian countries, upstream or downstream, are inadequate and in some cases non-existent resulting in bottlenecks that hinder effective flood forecasting and dissemination of flood warning (Samarakoon, 2004).

Arsenic contamination

The environmental problems are further complicated by the excessive arsenic problem, especially in the groundwater resources of the basin. Arsenic (As) is a natural constituent of the Earth's crust and is the twentieth most abundant element. It is released in the environment through natural processes such as weathering, which is aggravated by the problems of floods. An estimated 4,000 tons of labile As is annually transported in the GBM basin rivers (Breit *et al*, 2003).

The presence of As in groundwater in West Bengal is the most serious health hazard India has ever faced (see Map 2). As poisoning in West Bengal was first diagnosed in 1983.The first scientific paper published on As toxicity in West Bengal warned of the malignancy of the hyperkeratotic spots

Map 2: Arsenic contamination in West Bengal and arsenic enrichment in northeast India



Source: (1) http://www.soesju.org/arsenic/wb.htm (2) Devi, N. L., Chandra, Y. I. and Q. I. Shihua (2009), 'Recent Status of Arsenic Contamination in Groundwater of Northeastern India – A Review', in *Report and Opinion*, 1(3), p 22-32.

and liver if diagnosis was delayed (Garai *et al*, 1983; SOES, 2006). Diagnoses include melanosis, leukomelanosis, keratosis, hyperkeratosis, non-pitting edema, gangrene and skin cancer (Hindmarsh *et al*, 2002). According to the World Health Organization (WHO), consumption of water contaminated with arsenic levels of over 0.05 mg/l can cause skin lesions and even cancer. The sediment in the northern region contains a high percentage of clay and organic compounds (Acharyya, 1999), which may retain and release As in groundwater aquifers. Results of tests indicate increased As enrichment from east to west in northeast India (Baruah, 2003; see Map 2, p 31). Many areas in the northeastern states have As concentration greater than 0.05 mg/l, implying that millions of people are at risk of As poisoning (Singh, 2004). The concentration of As in the region generally varies from 0.02 to 0.9 mg/l, exceeding the WHO standard of 0.01 mg/l and the Bureau of Indian Standards benchmark of 0.05 mg/l (Linthoingambi *et al*, 2009). According to the North Eastern Regional Institute of Water and Land Management, a staggering 32,077 water sources have been contaminated with naturally occurring inorganic materials like arsenic, iron and fluoride (Linthoingambi *et al*, 2009). Podumoni, Assam shows a maximum of 67.57% As groundwater contamination (Linthoingambi *et al*, 2009).

Land

Land use change in the areas downstream of large projects is a major concern due to its livelihood and ecological impacts in terms of:

- Loss of fisheries;
- Changes in beel (wetland) ecology in the flood plains;
- Agricultural losses;
- Massive boulder extraction; and
- Sudden water releases from reservoirs in the monsoons, increasing flood vulnerability.

Shifting agriculture (jhum) is a dominant traditional land use in the hills of the northeast and plays a critical role in the livelihoods of people, maintaining agricultural diversity and providing food security. Increasing pressure on land has resulted in the shortening of jhum cycles (the length of the fallow period between two cropping phases), thus impacting its ecological viability. The submergence of land by hydel projects will further shorten the cycle and enhance pressure on surrounding areas, thus affecting the environment and livelihoods over a much larger landscape. In addition to submergence, land use restrictions will apply in the catchment area of the reservoir as per mandatory norms to reduce siltation and increase the life of the reservoir (Vagholkar, 2007).

Use of timber by industries and of forestland by development projects begins the process of deforestation. After exhausting forests in one village, the industrial agent goes to the next and the one after it, till most forests in a block are destroyed. Due to deforestation in their catchment area, the silting of major dams was 3 to 4 times higher than what was foreseen at their planning stage. It also reduced their lifespan substantially (CPR, 1985). Over 73% of the Brahmaputra river watershed's original forest is gone. Most of the eco-region's original semi-evergreen forests have been converted to grasslands. Only small patches of forests now remain. The remaining forests are disappearing at 10% per year. Currently only 4% of the land is under protected areas (Patkar, 2004). Compensatory mechanisms required as per forest laws to offset the loss of forests due to these projects also lead to protection of other areas by change of tenure and access regimes to land and resources (Vagholkar, 2007). The number of floods has grown during the last few decades. Studies show that most floods and related disasters are human-made, caused by deforestation in the catchment area of the rivers and by the rising riverbed. In India as a whole, 12.17% of the area is under threat, but the area affected is much higher in the main flood-prone states of Assam (50.14%) and West Bengal (37.42%)

(Bandyopadhyay, 2007). About 35% of the Majuli Island in Assam, the world's biggest river island, has already been lost to soil erosion (Goswami, 2003; Fernandes, not dated).

The Sunderbans are a particularly vulnerable ecosystem in the region. Over the last few decades the natural mangrove barriers have been destroyed to make room for the growing population and their aspirations. These massive land use changes have led to deleterious effects, as seen during cyclone Aila and the cyclones that preceded it. Over 70,000 people from the Sunderbans risk losing their habitat permanently due to sea level rise, increased cyclone intensity and flooding by 2030 (Hazra, 2007).

Socio-economic scenario

Any discussion on food security and poverty in the region is incomplete without profiling its economic conditions. This section will look at the poverty profile of the region and issues of governance and social exclusion that contribute to the complexity of the problem of food security and poverty.

The region under study has since, and even before independence, been subject to a variety of complex developmental aspects which contribute to its poverty dynamics. To understand these dynamics, it is essential to look at the basic demographics of the region (see Table 2). Barring West Bengal, the rest of the states form a small percentage of India's population. West Bengal is the most populated in the study area, with high levels of urban and rural poverty (Bandyopadhyay and Ghosh, 2009). Also, in the region under study, the majority of the population is rural, of which a great part are of the SC/ ST category that primarily depend on the environment for their livelihood and subsistence.

When looking at the region as a whole, the decadal changes in population indicate it is increasing at pace, especially with regard to the physical area (see Table 3, p 34). Ever-increasing population will cause a great stress on the existing natural resource base, which figures high on bio-physical vulnerability.

The classification of workers further supports this as the proportion of marginal workers is fairly high (see Table 4, p 34). The numbers in the non-working category signify pressure on the working population is disproportionately high to provide for the rest of the family (including children and elders). The number of pucca (permanent) houses in the state is a clear indication of the number of households living in either semi-permanent or temporary structures, thus impoverished to the extent of not being able to afford a permanent structure (see Table 5, p 34).

Table 2: Demography of the Indian states flanking Bangladesh

State	Population	% of National Population	Rural	Urban	Density (Persons/km^2)	SC/ST %
West Bengal	80176197	7.79	72	28	903	28.5
Meghalaya	2318822	0.23	80	20	103	86.4
Assam	26655528	2.59	87	13	340	19.3
Mizoram	888573	0.09	50	50	42	94.4
Tripura	3199203	0.31	83	17	305	48.5
India	1028737436+	100.00	72	28		24.4

Source: Registrar General of India, Ministry of home Affairs, Census 2001

Table 3 : Decadal change in population in Indian states flanking Bangladesh (%)

State	1901-1911	1911-1921	1921-1931	1931-1941	1941-1951	1951-1961	1961-1971	1971-1981	1981-1991	1991-2001
West Bengal	6.25	-2.91	8.14	22.93	13.22	32.80	26.87	23.17	24.73	17.77
Meghalaya	15.71	7.21	13.83	15.59	8.97	27.03	31.50	32.04	32.86	30.65
Assam	16.99	20.48	19.91	20.40	19.93	34.98	34.95	23.36	24.24	18.92
Mizoram	10.64	7.90	26.42	22.81	28.42	35.61	24.93	48.55	39.77	28.82
Tripura	32.48	32.59	25.63	34.14	24.56	78.71	36.28	31.92	34.30	16.03
India	5.75	-0.31	11.00	14.22	13.31	21.51	24.80	24.66	23.87	21.55

Source: Registrar General of India, Ministry of Home Affairs, Census 2001

Table 4 : Economic classification (% of total population)

State	Main Workers	Marginal Workers	Non Workers
West Bengal	28.7	8.0	63.22
Meghalaya	32.6	9.0	58.16
Assam	26.6	9.0	64.21
Mizoram	40.7	11.7	47.40
Tripura	28.5	7.7	63.70

Source: Registrar General of India, Ministry of Home Affairs, Census 2001

Table 5 : Permanent houses (%)

State	Permanent Houses
West Bengal	40.44
Meghalaya	22.14
Assam	19.47
Mizoram	52.84
Tripura	9.81
India	51.62

Source: Census of India 2001

Map 3: Poverty in the states flanking Bangladesh (as per BGRF)

Note: BGRF=Backward Region Grants Fund. Source: www.nird.org.in/brgf/index.html

To better comprehend the spread of poverty in the region, compared to the rest of the country, certain maps have been used based on the multidimensional poverty index and the data on the Backward Region Grants Fund (BRGF). The first map is on the multi-dimensional poverty index. This map shows that although the region under study isn't the second-most impoverished in the country; despite the abundance of water supply. Bio-physical vulnerability, political unrest and the physical isolation of at least the northeast from the rest of India are major contributing factors. Also, taking into account the population density in the region (especially in the northeast compared to the rest of India) the backwardness of the region is evident). This is corroborated with the mapping of the BRGF districts, which shows most of West Bengal and major parts of the northeast, especially Assam and Meghalaya, are backward (see Map 3).

The above data thus indicates that much of the population in the Indian sub-region under study is backward and poverty ridden. According to current estimates, about 36% of the people of northeast India are below the poverty level. In Meghalaya, for instance, 50% of the households are below the poverty level. It is a given that those who live below poverty level are unable to buy enough food. In fact the availability of all the food items taken together is much below the standard as recommended for a healthy life (Basu *et al*, 2006).

Agricultural productivity

Like the rest of India, agriculture is the mainstay of the livelihood for this region as well. The region which forms the middle course of the basin has been devoted to rice for centuries and to tea cultivation since colonisation by the British (Smadja, not dated).

Despite rich alluvial soils and abundant surface and groundwater, agricultural yield for a variety of reasons such as inadequate drainage, infrastructure and institutional arrangement (including marketing, combined rice-wheat productivity) plus unfavourable land tenure is estimated to be quite low at about 4-8 tons/ha/year (Sharma *et al*, 2008). The northeast states are characterized by a diverse agro-climatic and geographical setting. The valleys are fertile, rich in organic matter. Traditionally, farmers both in the upland terraces and valley land follow rainfed mono-cropping agriculture in which rice is the major crop, occupying more than 80% of the cultivated area, followed by maize (Ghosh *et al*, 2010). The region is prone to soil erosion and low agricultural productivity and input use is the norm. For instance, in Assam the yield of food grains per hectare in 2000-01 was 1,465kg compared to 4,040 kg in Punjab (Basu, 2006).

The per capita rice consumption in India is 82 kg per year, taking the total rice requirements of the study area to over 9 million metric tonnes (calculation based upon the population of 113,238,323 in the region). The present production is only about 2 million metric tonnes. Regardless of rice being the major staple food in the region, the average yield of it is implausible (see Table 6, p 36).

Despite great potential, the area covered by irrigation is dismally low as well (Basu, 2006). The basin as a whole is rich in groundwater resources which offer a big opportunity to enhance the livelihoods of the poor. Thus, while the population density and concentrated rural poverty are high, the untapped resource is large as well (Shah *et al*, 2000). This can be substantiated with data which shows insufficient amount of irrigated land with regard to the net sown area (see Table 7, p 36).

Evidence shows most of the rainwater flows away as run-off through sloping land, resulting in 70-90% of the areas remaining vacant during the Rabi season due to severe water scarcity. Farming, thus, is a high-risk activity in the region (Ghosh *et al*, 2010). A look at West Bengal, which contributes 8% of India's total food production, indicates the state is highly vulnerable to varying weather conditions. For instance, in 2005 the state suffered a crop loss amounting to Rs 525 crore due to

Table 6 : Area under principle crops ('000 ha)

State	Rice	Average Yield of Rice (Quintals per hectare)	Pulses
West Bengal	5784	25.7	40.0
Meghalaya	112	17.3	2.0
Assam	2377	14.6	9.0
Mizoram	55	18.9	0.5
Tripura	243	22.4	1.5
India	41907	19.8	9692.0

Source: Directorate of Economics and Statistics, Ministry of Agriculture 2004-05

Table 7 : Irrigation (%, net sown area)

State	Irrigated Area
West Bengal	55.65
Meghalaya	23.70
Assam	0.43
Mizoram	17.70
Tripura	14.20

Source: Directorate of Economics and Statistics, Ministry of Agriculture 2002-03

direct and indirect effects of weather hazards, especially very heavy rain and floods in the post-monsoon period (Mishra, 2007). Assam suffered similar losses in the 2004 floods. Such conditions lead to further impoverishment of the small and medium farmers who form the majority in the state.

Data further show the region under study is almost always food-deficit, importing grain from other parts of the country. The region is only able to meet about 50% of its foodgrain requirements (Basu *et al*, 2006). *Intensive natural resource mining and continuous degradation of natural resources (soil, water, vegetation) under conventional agriculture practices will not ensure farm productivity and food security* (Ghosh *et al*, 2010).

Fisheries

An important feature of coastal and marine livelihoods is their acute vulnerability to major shocks from natural disasters. The areas where these shocks are particularly frequent are in the eastern coast of India, of which West Bengal is a part (Townsley, not dated). Floodplain fisheries are an important component of the livelihood of the region. Any change in the water regime due to anthropogenic or climate-based changes can severely impact the fisheries sector. For instance, fish stocks are lost from cultured ponds when they are washed by floods. Abundant supply of good quality water combined with a traditional fish-eating population gives fisheries a high potential, although the achieved productivity is medium and could be increased significantly (Sharma *et al*, 2008).

Governance

The majority of the problems in these states can be attributed to poor governance structures and institutional management, especially when looking at floods. When calamities arise, very little discussion takes place (Dasgupta and Dey, 2010). The social and ecological impacts of large projects constructed to mitigate flood damage have not been assessed in the existing planning and decision-making process and do not reflect on the overall viability of projects (Vagholkar, 2007). Environmental laws and dependence on large engineering interventions have delayed solutions to pressing problems, especially of poverty and livelihoods (Goldsmith & Hildyard, 1985).

These problems of governance are both at the national as well as the international level, for there is no mechanism to monitor hydrological information and ensuring use of accurate data by all the co-riparian states (Goldsmith and Hildyard, 1985). At the national level, water resources management in all the co-riparian countries is fragmented among many agencies. Water Resources Councils have been established in India but they appear not to function.

The government, on paper at least, has been taking steps to alleviate the problems of development in the region. A package of fiscal incentives and other concessions has been approved for the northeast region, the 'North East Industrial and Investment Promotion Policy (NEIIPP), 2007', effective 1 April, 2007 onwards. In the case of West Bengal the government issued a Policy statement on Environment Protection and Conservation of Natural Resources on 5th June, 1995. It aims to reconcile pro-development and pro-environment goals. The basic thrust of this policy is to ensure the tempo of developmental activities is increased and facilitated by also taking into account the preservation and conservation of environment and natural resources.

The nature of the public distribution system (PDS) for food in the northeastern region, for instance, shows governance structures in a really shoddy light. Problems in agriculture are further compounded by the lack of institutions related to credit, marketing and delivery (Basu *et al*, 2006). Food availability due to low agricultural productivity is deplorable in the region, with Assam and West Bengal figuring high among the states that have rural households facing a food crisis all year round (Mitra, 2007). There have been an alarming number of starvation deaths in the region. West Bengal, in fact, has the highest percentage—10.6%—of rural households that are food-deficit during particular months of the year, according to a 2007 National Sample Survey report. The northeast is even worse off.

PDS efficiency is compromised by poor delivery mechanism, poor infrastructure and inadequate coverage in hilly and tribal belts. Thus the system has failed to reach its target audience in the region (Basu *et al*, 2006). Not a single grain supplied to Meghalaya, Mizoram and Assam reaches the targeted population (Naik, 2010). In Assam, many of the PDS commodities like kerosene oil, pulses and wheat flour have not been reaching PDS centres. Numerous families are not even aware about the existence of PDS and the government has not made an effort to raise awareness about this entitlement (Action Aid India, 2009). In West Bengal as well, problems in the PDS system have led to several protests by poor farming communities. Dependence on PDS is very high in West Bengal because though the per capita production of food in the state is high, people don't have purchasing power to buy food (Mitra, 2007). Overhauling PDS is critical: removing distributors and dealers, replacing them with self-help groups and cooperatives and issuing digitized ration cards will really help improve it (Mitra, 2007).

Forced migration

This issue in India's east and northeast deserves attention, by looking at issues of border and boundary conflicts, security, refugees, the large presence of internally displaced persons in the region due to various conflicts and development projects, mass-scale displacement due to natural disasters and environmental degradation leading to resource conflicts in recent times (Dasgupta and Dey, 2010). These states have been subjected to the compulsions of development projects that directly affect the poor and powerless indigenous population groups of the hills and the plains as well as economically backward agricultural communities (Dasgupta and Dey, 2010). In the early 20th century, expansion of the railroads by the British colonial government, without assessing its impact on the course of rivers in their path, hindered drainage and triggered floods. Another factor was the rampant construction of barrages by landlords for the safety of their estates and agricultural land. The hasty implementation of projects in the years immediately following Independence has been criticised (Dutta, not dated).

Environmental problems, loss of soil fertility act as an indirect coercion for people to abandon their land (Ganguly, 1999). Since these people are not directly forced out of the area by authorities, they are considered voluntary emigrants. A huge number of such people are known to exist, but there is a no methodology for an estimate. Moreover, in case of the tribal population and those dependent on natural resources for their livelihoods, their displacement means destructive dependence on the environment (Fernandes, not dated). In West Bengal and Assam, about 50% of project-displaced tribal families have made a transition to destructive dependence (Fernandes *et al*, 2006).

Vulnerable locations and groups

The existence of socially vulnerable groups and marginalized communities, slow pace of economic growth, increasing rate of population, underutilization of natural resources in certain pockets and institutional and systemic inadequacies shape the hazard scenario in the region (Goswami, 2003).

In spite of a period of economic prosperity, poverty decline for the indigenous communities, referred to as Adivasis or Scheduled Tribes (STs), has been even slower, particularly in states with large proportions of tribal population (World Bank, 2010). In fact, two Bangladesh-bordering states, Meghalaya and Mizoram, have the highest tribal population in India, 94.5% and 85.9% respectively. Excess mortality of tribal children continues to be the starkest marker of tribal disadvantage, with roots in complex processes that exclude STs in general. Trends in child nutrition status in the states under study further verify this state of affairs.

The lack of a say in decision-making and alienation from land and forests are central to tribals' continued exclusion from development (World Bank, 2010). These communities are also vulnerable to surprise disasters which often are due to unplanned infrastructure. Floods were an annual event in states like Assam. But they have become more frequent and intense over the last five decades. For example, in 1953 they affected 410,000 persons in Assam. By 1998 this number had risen to 4,698,000. In 2004, the worst floods in Assam in 50 years killed 250 people (Fernandes, not dated).

The vulnerability of people increases due to their nomadic nature and due to development which doesn't take into consideration social and environmental factors. The disaster in Bolbola, a village 80 km away from Guwahati, is an example where people had migrated from the northern bank of the Brahmaputra to the southern side. A flash flood took place, taking the lives of a number of people. The situation was further aggravated by the media reporting it as a dam burst in Meghalaya. In reality, a new railway line had been created and the entire residential area went under the vacated tract of a reservoir. Almost 150 people died in the disaster and there was no place to bury the bodies. An uphill village was approached for land to dispose the bodies (Dasgupta and Dey, 2010).

Vulnerable areas of the northeast include the flood plains of the Brahmaputra, where its tributaries are shifting. This region is vulnerable in terms of the high frequency of floods. For instance in Assam, food insufficiency is acute amongst the households displaced by floods, and the shifting

In the northeast states, high biophysical vulnerability coupled with low socio-economic indicators increase the overall risk posed to the population. Issues in the region are well known: now, the causality has to be established

of the river in the Brahmaputra valley. Women-headed households, especially those of the Koch-Rajbonshi area in western Assam, migrant labour among ex-tea communities and immigrant Muslims in Char areas are the most vulnerable groups (Centre for Humanistic Development, not dated).

Due to the shortages caused by industrial agents with regard to forest resources, the forest dwellers make a transition from constructive to destructive dependence on the same resource for sheer survival. With the depletion of forests they lose access to the food and other needs of theirs that the forests had traditionally met. Impoverished by and deprived of their basic needs, they fall prey to the moneylenders, lose their land to them and often become their bonded labourers (Fernandes, Menon and Viegas, 1988).

The nature of coastal and, in particular, fishing communities in India, where the problem of food security is most significant, tends to make these communities particularly vulnerable to food crises on a seasonal basis. Many fishers have extremely limited access to land or to alternative livelihood options to see them through seasonal variations in fish catch (Townsley, not dated). The condition of these communities has worsened due to their low social status (Townsley, not dated). Access to productive land can be restricted, either because of the low status of fishing communities, as in India, or the marginalisation of fishing communities in remote areas where land is of poor quality. In remote coastal areas, services are often limited and access to institutional support of any kind can be difficult (Townsley, not dated). In case of shortages, fishing communities also violate their progressive rules on preservation such as a ban fishing during the monsoons.

Situational analysis

The nature of problems in the region reflects its environmental characteristics, socio-cultural complexity and political sensitivity. The high biophysical vulnerability of the region coupled with poor socio-economic indicators increase the overall risk posed to the population. Food security and poverty form a vicious cycle of distress for the population, perpetuated by these factors. Many of these issues are well known, but their causality has seldom been established.

The region under study has a high number of people living in poverty, or is generally backward in economic parameters. This is despite the fact that the region features high in literacy rates as well as the sex ratio. A lot of it can be related to issues of social hierarchy. A large part of the population falls under the SC/ST categories with Meghalaya and Mizoram being huge tribal belts. Social exclusion apart, economic pressures further intensify the poverty cycle. For instance, health concerns can cause expenditure on medical care and increased economic pressure on the household due to loss of productive days leading to further impoverishment of the people. High As concentrations in groundwater are a major concern and initiatives to manage it are imperative, due to the health risks associated with the consumption of arsenic-contaminated water.

Governance is an overarching concern that affects the region and its inhabitants. It directly impacts the water and development regimes. Weak government structures and lack of implementation policies are clearly visible in low agricultural and fishery productivity and inefficiency of the PDS.

Development in the region has mostly been haphazard although huge sums of money have been utilised. It has not taken into consideration the impacts on the lives of the people, especially the poor and the nomadic. Natural degradation leading to land-use change due to the construction of large projects like dams and hydroelectric plants—168 public and private large river hydropower-dam projects with a cumulative capacity of over 63,000 MW are being planned for the region—reduces the share of agricultural land in the region.

The jhum cultivation characteristic of the northeastern states is also compromised with land use change especially in the forested region. There are shorter cycles of rotation due to limited availability of land leading to further environmental destruction. As a result, productivity of land also gets reduced due to soil nutrient depletion and soil erosion, directly impacting food security.

Production of pulses in the area is non-existent traditionally and since agricultural productivity is low, fisheries assume greater importance for food security as protein supplements. Traditionally, rice and fish form the staple diet in the region. Fisheries have a huge potential in the area but it has not been realized due to lack of institutional support. However, fishermen are also an impoverished community, traditionally placed low in the social hierarchy. In the off-season, the community lacks alternative means of livelihood. In addition, high-potential sectors like fisheries and forestry are not optimally tapped.

Another reason for high levels of food insecurity in the region is the poor delivery mechanism of the PDS. Poor rail and road connectively disrupts smooth working of the system. Environmental vulnerability drastically affects productivity in both land- and off-land systems, and so the reliance on PDS to meet nutritional requirements is fairly high. Food security studies carried out by various organizations do not reflect the insecurity in the region, due to lack of data from this region. Assam and West Bengal, it is known, have high level of food insecurity ranging from 0.49 to 0.62 (MSSRF, 2008). Thus, whatever development does take place its distribution is not equitable, with the tribal and backward populations terribly lagging on development indicators, especially in the northeast. Floods further damage agriculture and fisheries, the two prime livelihoods, threatening food security in the region. Development of industries in the region, which could act as an alternative source of employment, has also been inadequate despite a number of fiscal incentives.

Disturbance in the area and the low scope for growth thus increases both intra- and inter-region migration. This is especially true in the northeast. Conflicts and a high degree of migration increase the helplessness of a population in an area of high bio-physical vulnerability. These factors together contribute to their poor adaptive capacity.

Since the waters are shared between five countries, with the study region being an intermittent part, water management is a serious concern. Recurrent floods are characteristic of the both the northeast (Brahmaputra) and West Bengal (Ganga). These waters can be productively managed for purposes of irrigation and other development initiatives; however, the abundantly (if not in excess) available water flows down as run-off, causing floods in low-lying regions.

The government has tried to respond to these issues through various policy incentives and programmes. Many of them have been misguided and have had an opposite effect on the people. There is a need to better understand the complexity of the scenario and to ground plans and programmes so benefits reach the target group. Food security is a basic need of the people and is a sensitive issue, especially with respect to the trans-boundary resource sharing in the study area. This section attempts to bring out the links between key issues that need to be addressed in future studies.

The way ahead

Research needs to understand the causes, effects and mitigation measures of dealing with the problems of the region. Based on the understanding developed during the course of the study, there are a few areas that require urgent research:

- **Role of fisheries in providing food and livelihood security**

  Fisheries are an important sector in the region due to the high potential they offer and the benefits in terms of nutritional and livelihood security. The sector is currently not tapped adequately. Also, there are no institutional support systems to ensure large-scale roll out. These institutional lacunae in a high biophysical-risk sector are a major deterrent. Research needs to understand the full potential of the sector and the impact climate change and governance mechanisms can have on its uptake.

- **Understanding the cause and effect relationship of migration on food security and poverty**
  Widespread migration is rampant due to ethnic conflict, environmental vulnerability especially due to freak weather events and lack of adequate employment opportunity in the region. Research needs to better understand the causes, effects and mitigation measures of this large-scale forced migration in the light of increasing food insecurity and poverty. The role of local governance in mitigation measure needs to be explored.
- **Effect of environmental degradation (arsenic, sedimentation) on food production**
  Food production is directly linked to both food security and poverty. Rice is the staple crop of the region. Rice production in the region is already inadequate in terms of meeting the needs of the population. In addition, environmental problems of floods and associated erosion and sedimentation concerns adversely affect production. Impacts of these issues need to be scientifically understood and validated.
- **Shortage of fresh water affecting the ecosystem of the Sundarbans**
  The Sunderban ecosystems are very vulnerable especially due to climate change impacts. This biodiversity hotspot provides for the basic needs and livelihoods for thousands of people. Hence any adverse impact on the ecosystem will severely affect them. The Sunderbans depend on fresh water flows for their survival. Research needs to quantify and offer mitigation solutions to the impact of changing environmental flows on the ecosystem and the lives of people dependent on it.
- **Exploring channels of data sharing and regional cooperation with regard to shared water resources**
  There is a lack of adequate and accurate data and knowledge-sharing and transparent institutional mechanisms to do so. The two countries being studied share their natural resources as well as associated problems. They have common concerns of food security and poverty. Regional cooperation in finding combined solutions is needed, especially in the light of inter- and intra-regional conflicts and the high vulnerability of the population discussed above. In order to understand these issues, there is also a need to study state, national and regional policies and laws pertaining to the region and suggest platforms for transparent information sharing.

The need for research is heightened due to the lack of region-specific information available on food security and poverty issues specifically the impacts of climate change and globalization. Researching these various themes would deepen understanding of existing problems and direct the way towards an actionable plan for alleviating food insecurity and decreasing poverty in the basin.

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Are people in riverbank areas more vulnerable?

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The agro-ecological zones of Bangladesh constitute a major part, 80%, of the total alluvial floodplain of 144,000 sq km formed by the Ganga-Padma, Meghna and Jamuna-Brahmaputra rivers and their tributaries (FAO/UNDP, 1988); these zones exist in the form of active river floodplains, meander floodplains, piedmont plains, estuarine floodplains and tidal floodplains. The 80,500 sq km river floodplains (Brammer, 1997) are essential for the livelihoods of many among 147 million people due to existing wide-scale smallholder-intensive subsistence agriculture (UNPRB, 2006). Rural socio-economic development is closely associated with agricultural growth involving intensive land cultivation (Turner and Doolittle, 1978) or output from per unit of land with various necessary agricultural inputs. There is a view (FAO, 1997) that food security at the farm household level is a matter of an individual household's access to enough food. Thus, it is closely linked with issues of poverty, access, sufficiency, vulnerability and sustainability. At the household level, food security is measured by actual dietary intake of all household members using household income and expenditure surveys. Inability of people due to poverty has been used as a proxy indicator for measuring food insecurity (Smith *et al*, 2000). "Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food which meet their dietary needs and food preferences for an active and healthy life" (World Food Summit, 1996). Food security encompasses many issues, ranging from food production and distribution to food preferences and health status of individuals. Food security in Bangladesh is characterised by considerable regional variations. Factors such as a tendency towards natural disasters, distribution and quality of agricultural land, access to education and health facilities, level of infrastructure development, employment opportunities, and dietary and caring practices provide possible explanations (World Food Programme 2011).

Concern over sustainability of agriculture and food security in Bangladesh is mounting in the context of deteriorating land quality, declining yield and increasing population. To increase crop yield from the scarce arable land farmers are intensifying land use, utilizing inorganic fertilizers, pesticides, irrigation equipment and other technologies (Hossain, 1988). However, agricultural activities in Bangladesh are frequently affected by natural calamities such as floods, cyclones, tornadoes, drought and pest infestations. About 20-25% of the country is flooded because of the concentrated rainfall during the monsoon; 50-70% gets inundated due to intermittent or extreme rainfall (Hossain, 2006), and invariably the crop damage is massive (Shahabuddin, 1999). One-fifth of Bangladesh is flooded every year; in years of extreme rainfall, two-thirds of the country can get flooded (Mirza, 2002).

When agricultural lands flood, there may occur a dual impact on crop production. There may be crop loss due to flooding; equally, there may be higher crop yield the subsequent year due to rejuvenation of land after flooding. However, it is assumed climate change-induced changes in precipitation patterns, in terms of delayed or advanced onset and withdrawal of monsoon as well as increased monsoon precipitation, will impact flooding characteristics across the GBM region. Thus, there might be changes in the timing major rivers peak, and so an increase in the magnitude, frequency, depth, extent and duration of floods (Mirza, 2002). Nevertheless, within the existing synergy of global demographic growth, increased competition for water and improved attention to environment issues, water for food exists as a core issue that can hardly be tackled through a narrow sectoral approach. New forms of water management in agriculture, including rain-fed and irrigated agriculture, watershed management, inland fisheries and aquaculture and livestock and rangeland management need to be explored and implemented in a comprehensive way. Farmers can play the role of change-makers for conservation of biodiversity and natural ecosystems through minimizing negative impacts of intensive agricultural practices, if supported with appropriate incentives and governance practices. It is necessary irrigation institutions respond to the needs of farmers, ensure more and reliable delivery of water, increase transparency in their management and balance efficiency and equity in access to water. This will require changes in attitudes together with well-targeted investments in infrastructure modernization, institutional restructuring and upgrading of the technical capacities of farmers and water managers. Management of trans-boundary waterbodies for the benefit of the whole ecosystem and livelihood practices would probably be worth concentrating in this regard.

Cropping diversification may help farmers minimize risk arising from natural hazards. However, this has caused major changes in cropping patterns, use of agricultural inputs and management of soil fertility. Traditional cropping practices, such as mixed cropping, crop rotation, and intercropping have disappeared gradually (Hossain and Kashem, 1997). This has led to monocropping and higher dependency on external inputs such as irrigation, inorganic fertilizers and pesticides. Monocropping along with imbalanced use of inorganic fertilizers and pesticides and intensive land-use without application of organic fertilizers have led to deterioration of soil quality and fertility (Hossain and Kashem, 1997; Rahman and Thapa, 1999; Task Force Report, 1991). More than 65% of the total agricultural area is suffering from declining soil fertility, and about 85% of net cultivable area has organic matter below the minimum requirement (Hossain, 1990; Task Force Report, 1991). As a result crop yields are decreasing steadily, despite increased use of agricultural inputs (Ahmad and Hasanuzzaman, 1998; Ali, 1995; Hossain and Kashem, 1997; Pagiola, 1995; Rahman and Thapa, 1999). The increased use of inorganic fertilizers, insecticides and pesticides has led to contamination of waterbodies and the spread of diseases, which have adversely affected aquatic life, livestock and people (Hossain and Kashem, 1997; Rahman and Thapa, 1999). Likewise, the excessive use of groundwater is suspected to be the cause of the presence of high levels of arsenic in groundwater in the northern and northwestern parts of Bangladesh (Ullah, 1998). Ensuring food security for the huge population through sustained agricultural production within the existing synergy of declining soil fertility, decreasing yields, increased and imbalanced use of inorganic fertilizers and pesticides has become a serious challenge for Bangladesh.

Sustained agricultural growth induces change in the rural system that includes changes in bio-physical environment (land use/land cover), economic infrastructure (cropping intensity, land, labour, technological productivity and farm income) and social conditions (literacy, housing, transport) in rural areas. For balanced agricultural and rural development planning, in which agricultural growth and the smallholder's socio-economic well-being would continue simultaneously (as per the national standard), the level of agricultural growth and rural socioeconomic change should be understood in the context of demographic, market, environmental, institutional and technological factors that configure them. Existing studies on Bangladesh agriculture and rural development have examined the conditions of micro-level agricultural intensification and change (Ali, 1987, 1995; Turner and Ali, 1996); the public policy and political-economic issues of rural development, micro-credit and energy systems; and the role of women in agriculture and socioeconomic development (Ahmed et al., 2001; Amin *et al*, 1994; Bayes, 2001; Biswas *et al*, 2001; Blair, 1985; Hye, 1989; Matin and Hulme, 2003; Rahman, 1996; Rahman, 1999; Sharif, 1992). But these studies have not explored the nature and causes of rural system changes in the context of their proximity to active river flows. An understanding of such changes may have significant policy implications. Water availability would of course potentially influence the livelihood in the whole GBM region; however, it might be assumed that the immediate impact would be on agricultural practices in areas near river flows. Thus, this study is aimed at finding the status of food security and poverty between the households living close to the three major rivers in Bangladesh.

Study framework

The study is based on the concept that the change of agricultural practices—cropping intensity, cropping pattern, proximity of villages to river flows, income from agriculture and so on—causes change in rural livelihoods, in occupation, land ownership, poverty and food security. Additionally, proximity of villages to the major rivers Ganga, Brahmaputra and Jamuna would influence agricultural practices and thereby livelihoods, for instance, in terms of poverty and food security. It is generally understood that if the household size grows the demand for food also increases. In subsistence agriculture system, cropping intensification increases total food production and ensures household food security. Hence, it might be assumed that over time there would be increased cropping intensity, change of cropping schedule, agricultural inputs for secured crop production, thus reducing risk in the GBM region.

Agriculture in Bangladesh in the northern districts is being affected due to seasonal drought. There have been 20 drought incidents during the last 50 years in the country, which led to a shortfall of rice production of 3.5 million tons in the 1990s in the north-western region. It is assumed that

Change in agricultural practices—cropping intensity, cropping pattern, proximity of villages to river flows, income from agriculture and so on—causes change in rural livelihoods, in occupation, land ownership, poverty and food security

current severe drought can affect yield in 30% of the country, reducing national production by 10 %. A temperature increase of 0.5°C and annual rainfall reduction of 5% could reduce runoff into the Ganges, Brahmaputra and Meghna by 14%, 11% and 8%, respectively. With 12% reduction in runoff, the population living in severe drought-prone areas might increase from 4% to 9% (CCC, 2009).

Nevertheless, in the northern region of Bangladesh, farmers usually cultivate long-duration high-yielding varieties of rice, BR11, from July to November (Aman rice), and BRRI rice 28 or BRRI rice 29 during January-May (Boro rice). Since Aman rice is harvested at the end of November and transplanting of Boro rice starts from January, the landless agricultural labourers face slack seasons of employment during October-November. Consequently, they have to face starvation during this period, which is popularly known as monga (BRAC, 2011). The basic explanation of the monga phenomenon is widely known: employment and income opportunities of the rural poor strongly decrease between transplantation and harvest of paddy. The lack of income reduces their ability to cover nutritional requirements (Zug, 2006).

In addition, coastal agriculture is being seriously affected by different levels of climatic risks caused by integrated effects of the following factors: soil salinity, water salinity, sea level rise, tidal surge, cyclone, heavy soils, soil wetness/water stagnancy, fallow/seasonal fallow land, incidence of pests and diseases, fishermen's joblessness, migration to cities and unsafe drinking water. Additional factors impacting development of agriculture include poor marketing infrastructure, the problem of agro-based industries and the poor health of farmers (Miah, 2010).

However, rather than restricting this study merely to the drought-prone northern districts and salinity-affected coastal region, an attempt has been made to reveal the overall poverty and food security situation with respect to trans-boundary water flow throughout the country.

Methods and sources of data

The study is based on secondary data, collected from a multitude of organizations such as IFPRI, IRRI and BRAC RED. The original dataset extends over 20 years (1988-2008). However, for this study, data from the years 2000 and 2008 have been used to form a panel dataset. A multi-stage random sampling was used to select the sample for the study. The initial dataset included 62 villages. Here, 21 villages have been selected purposively, in terms of proximity to nearby active rivers, to conduct a poverty and food security situation analysis. Nine of these villages, termed as riverbank areas, are within a limited distance (0.25 km) from the GBM riverbanks, while the remaining 12 are significantly far away; they are termed comparison villages (see Map 1). The rest of the 41 villages were left out due to their ambiguous location within our framework.

It was assumed the agricultural system of the study areas would influence the poverty and food security of the villages lying near the river more than those were further away. The survey collected information on the basis of similarities. A census of all the villages was carried out on socioeconomic features such as ownership of land, major sources of income, education of the household wage earners, cropping intensity, cropping pattern and so on. Primarily, 30 households were selected from each village during 2000, which were re-visited in 2008 for collecting necessary data. Thus, panel data of 235 households from the riverbank areas and 312 households from comparison areas have been used to analyze the poverty and food security situation with respect to the location of villages from the nearby river.

'Household poverty' is defined here in terms of total household income and expenditure for consumption of 2,100 kcal food per person per day. 'Cropping intensity' is defined as the total cultivated land as percentage of total cultivable land.

Map 1: Villages (riverbank and comparison areas) in the study

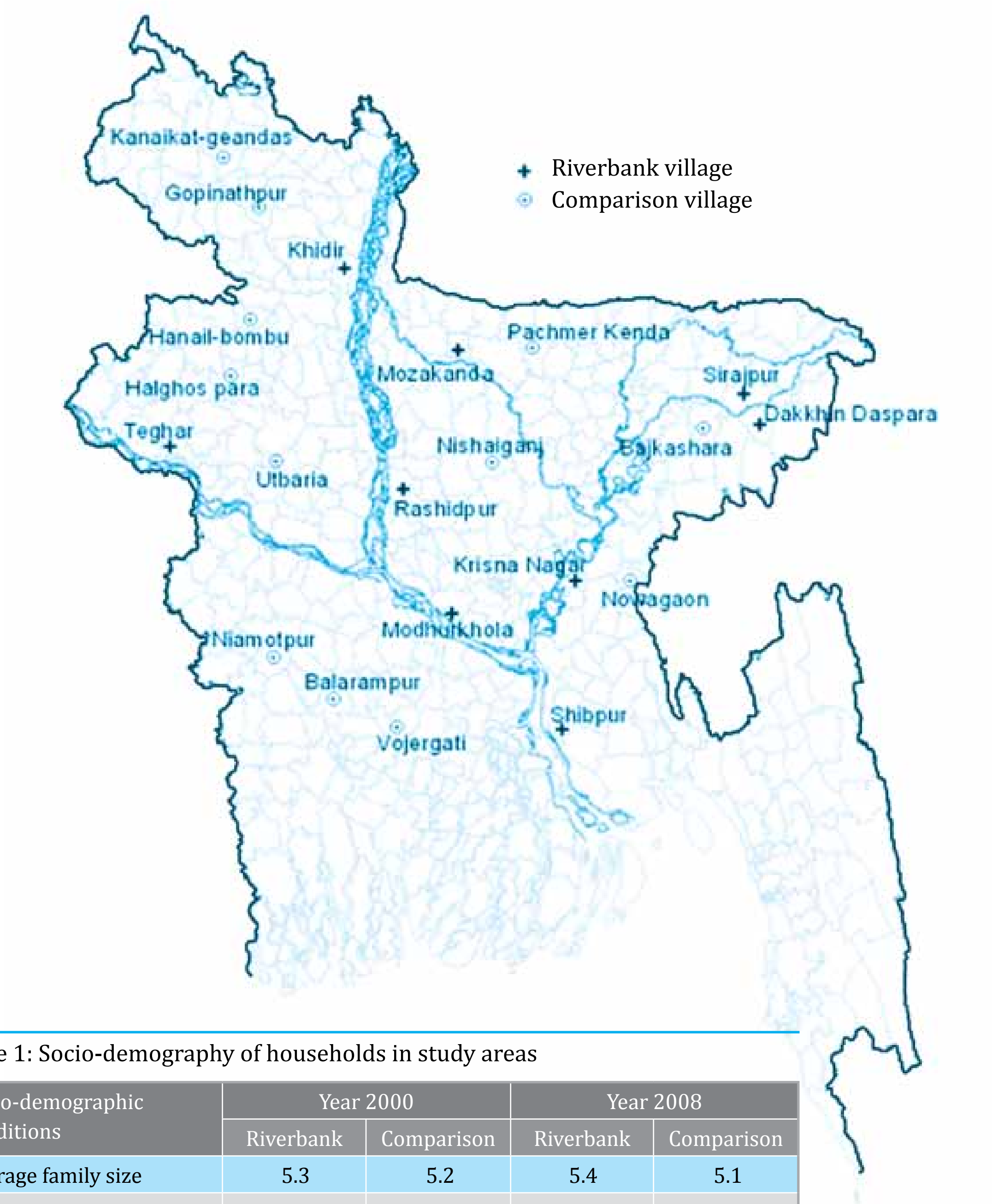

Table 1: Socio-demography of households in study areas

Socio-demographic conditions	Year 2000		Year 2008	
	Riverbank	Comparison	Riverbank	Comparison
Average family size	5.3	5.2	5.4	5.1
Average year of education of household wage earner	3.6	4.1	3.7	4.3
HHs having electricity (%)	32.1	34.7	53.2	62.0
N	235		312	

Map and data in figures 1 and 2 and all tables are based on BRAC datasets

Socio-economic situation analysis

To begin, a socio-demographic profile of the households in the study areas shows there was no significant difference in average family size in riverbank and comparison areas both in 2000 and 2008. However, the family size slightly increased in the riverbank areas, while it reduced slightly in comparison areas resulting in the higher difference in family size between the two areas in 2008. The national level average household size was reported to be 4.8 (BBS, 2004). The average year of education of household wage earners increased over time and the education status of wage earners in comparison areas was better than the riverbank areas. There was significant ($p<0.01$) increase in households with access to electricity both in the riverbank and comparison areas from 2000 to 2008. Though there was no significant difference in the number of households having electricity access between riverbank and comparison areas in 2000, the number of households with electricity access was significantly ($p<0.01$) higher in the comparison areas in 2008 (see Table 1, p 49).

Occupation of household heads

Household heads involved in agriculture and service increased significantly ($p<0.01$) from 2000 to 2008 in the riverbank areas. There was decrease in the number of household heads involved in business and selling labour (agricultural or non-agricultural) during 2000-2008. Contrary to the riverbank areas, household heads involved in agriculture and agricultural labour reduced from 2000 to 2008 in the comparison areas. Though there was reduced number of household heads involved in non-agricultural labour, involvement in business and service increased over time in the comparison areas (see Figure 1).

In the comparison areas 9% more household heads were involved in agriculture than the riverbank areas in 2000; however, this difference disappeared in 2008 between two areas. It is also remarkable that, in 2000, 5.9% less household heads in the comparison areas were involved in business compared to the riverbank areas, which shifted to 2% more increase in involvement in business in 2008. Thus it may be assumed that the opportunities of business in the comparison areas increased over time than in the riverbank areas (see Table 2).

The occupational transition of household heads, 2000-2008, shows that in both riverbank areas and comparison areas a majority of the people (36.6% and 42.4%, respectively) stayed steady with agriculture. In addition, a quite considerable proportion of people involved in other occupations—agricultural labour, business, service and non-agricultural labour—both in the riverbank and comparison areas shifted to agriculture from 2000 to 2008 (see Table 3). Thus, agriculture seems to be the major occupation in the study areas, influencing the overall socio-economic condition.

Land ownership

Thus, it is logical to look at the pattern of land ownership in both areas and how it changed over time (see Table 4, p 52). A majority of the households owned up to 0.2 ha of land in 2000 and 2008 in both areas and the proportion of such smallholders was higher in the riverbank areas. However, the share of such smallholders of the total land was minimal both in the riverbank (7.5-8%) and comparison villages (2.8-5.3%), 2000-2008. On the other hand, the proportion of households owning more than 2 ha land reduced both in the riverbank and comparison areas during 2000-2008, which was significantly ($p<0.05$) higher in the comparison areas. Large-size land owners constituted a major share of the total land in the comparison areas both in 2000 and 2008, though it reduced by 13.7% over time. On the other hand, there was only a minor decrease in the number of large-size landowners

Figure 1: Occupation of household heads in study areas

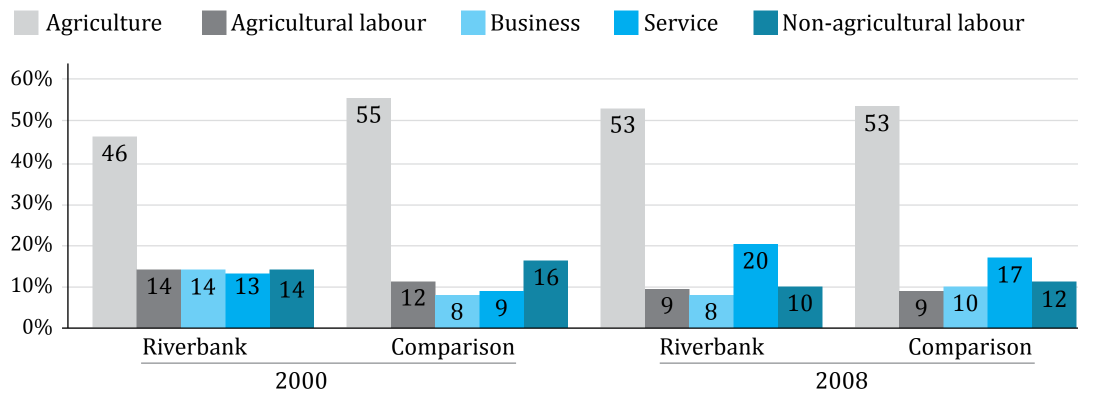

Table 2: Difference in occupation of households in study areas

Head occupation	Difference in 2000	Difference in 2008
Agriculture	9.5	0.4
Agricultural labour	-2.1	-0.4
Business	-5.9	2.0
Service	-4.2	-3.8
Non-agricultural labour	2.7	1.8

Table 3: Transition of occupation in study areas from 2000 to 2008

Occupation of HH heads in 2000 (%)	Occupation of HH heads in 2008 (%)				
	Agriculture	Agricultural labour	Business	Service	Other labour
Riverbank					
Agriculture (46.0)	79.6	3.7	3.7	12.0	0.9
Agricultural labour (13.6)	28.1	25.0	12.5	6.3	28.1
Business (13.6)	31.3	6.3	31.3	21.9	9.4
Service (13.2)	29.0	3.2	0.0	67.7	0.0
Non-agricultural labour (13.6)	31.3	21.9	0.0	15.6	31.3
Comparison					
Agriculture (55.4)	76.9	3.5	5.2	11.0	3.5
Agricultural labour (11.5)	30.6	36.1	2.8	8.3	22.2
Business (7.7)	29.2	0.0	58.3	8.3	4.2
Service (9.0)	14.3	0.0	7.1	75.0	3.6
Non-agricultural lab (16.3)	21.6	17.6	7.8	13.7	39.2

Table 4: Changes in the distribution of land ownership

Land ownership (ha)	2000				2008			
	Riverbank		Comparison		Riverbank		Comparison	
	% HH	% share	% HH	% share	% HH	% share	% HH	% share
Up to 0.20	53.6	7.5	44.6	2.8	51.9	8.0	47.4	5.3
0.20 – 0.40	11.5	8.4	15.1	6.3	16.6	12.9	12.5	8.1
0.40 – 1.0	22.6	35.0	20.5	20.4	21.7	34.6	19.2	24.5
1.20 – 2.00	8.9	29.6	10.9	23.2	6.8	25.5	13.5	28.8
Over 2.00	3.4	19.5	9.0	47.2	3.0	19.0	7.4	33.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Avg cultivated farm size (ha)	0.53		0.87		0.47		0.68	

and their share of total land in the riverbank areas. Thus, the overall trend is that the number of small- and medium-size landholders increases, while the number of large-size landholders decreases.

The average farm size used for cultivation reduced significantly ($p<0.01$) in both areas over time. The average farm size in the comparison areas was 0.34 ha larger than the riverbank areas in 2000, reducing to 0.21 ha in 2008 (see Table 4). This might indicate there was higher land fragmentation and utilization of cultivable land for other purposes in the comparison areas.

It has been reported (Hossain, 2009) extreme population pressure in Bangladesh renders very low household-level endowment of land. There is only 3.75 mha arable land in the country to support 147 million people. The land-man ratio is decreasing at an alarming rate. The current estimated per capita arable land stands at 0.05 ha only (Hussain and Asaduzzaman, 2009).

Annual cropping pattern

So far as the year 2000 was concerned, the cropping pattern as well as the cropping intensity of both the riverbank and comparison areas showed that the cropping practice in the riverbank areas was more intensive as compared to the cropping practice of the comparison areas (see Table 5). The proportion of land left fallow throughout the year in the riverbank areas was less than in the comparison areas. However, in the comparison areas, a higher proportion of land was used for the purpose of single cropping than in the riverbank areas. Concomitantly, in the comparison villages, the proportion of land that was used for two and three crops in a year was comparatively less. Thus, it is found that the cropping intensity in the riverbank areas was higher (168%) than the comparison areas (139%). However, the cropping intensity of Bangladesh during 2000-2001 has been reported to be 176.98 (BBS 2010).

So far as 2008 was concerned, the cropping pattern in the comparison areas contradicted with that of 2000 when compared with the riverbank areas, with incidents of reduced fallow land, less single cropping but more double cropping. The practice of cultivating three crops in a year was identically higher in the riverbank areas in 2008 as well. Nevertheless, the overall cropping intensity in the riverbank areas presumably decreased over time and, in 2008, the cropping intensity in comparison areas was as high as 166.4% (see Table 6). However, the cropping intensity of Bangladesh during 2008-2009 has been reported to the 179.0 (BBS, 2010). In both areas rice is the major crop, though alternative crops like pulses, vegetables, potato, sugarcane and jute are also grown.

Table 5: Annual cropping pattern and cropping intensity in 2000

Cropping pattern	Riverbank			Comparison		
	N	Land (ha)	Land (%)	N	Land (ha)	Land (%)
Fallow	9	0.90	1.3	19	2.90	1.7
Rice + fallow	128	17.20	24.3	354	70.10	41.6
Other crop + fallow	57	7.90	11.1	52	4.50	2.6
One crop	185	25.13	35.4	406	74.59	44.2
Rice + Rice	207	25.40	35.8	374	63.70	37.8
Rice + Other crop	88	10.40	14.7	122	20.20	12.0
Other crop + Other crop	36	4.50	6.3	26	2.30	1.4
Two crop	331	40.28	56.8	522	86.21	51.1
Other crop + Rice + Rice	2	0.40	0.6	43	4.40	2.6
Other + Rice + Other	34	4.00	5.6	5	0.50	0.3
Other crop + Other crop + Other crop	1	0.20	0.3	-	-	-
Three crop	37	4.60	6.5	48	4.83	2.9
Total	562	70.90	100.0	995	168.60	100.0
Total crop area (ha)	119			262		
Cropping intensity (%)	168.0			139.1		

Table 6: Annual cropping pattern and cropping intensity in 2008

Cropping pattern	Riverbank areas			Comparison areas		
	N	Land (ha)	Land (%)	N	Land (ha)	Land (%)
Fallow	2	0.19	0.3	5	0.99	0.8
Rice + fallow	141	20.07	32.3	188	40.89	31.8
Other crop + fallow	71	11.58	18.7	44	7.57	5.9
One crop	212	31.66	51.0	232	48.46	37.6
Rice + Rice	145	19.08	30.7	352	59.53	46.3
Rice + Other crop	34	4.89	7.9	72	8.83	6.9
Other crop + Other crop	13	1.74	2.8	32	3.31	2.6
Two crop	192	25.72	41.4	456	71.68	55.7
Other crop + Rice + Rice	3	0.20	0.3	1	0.10	0.1
Other + Rice + Other	35	4.32	7.0	36	7.21	5.6
Other crop + Other crop + Other crop			0.0	1	0.27	0.2
Three crop	38	4.52	7.3	38	7.58	5.9
Total	444	62.09	100.0	731	128.71	100.0
Total crop area (ha)	97			215		
Cropping intensity (%)	155.7			166.4		

Table 7: Difference of cropping pattern in comparison areas from riverbank areas

Cropping pattern	2000			2008		
	Land in riverbank areas (%)	Land in comparison areas (%)	Difference in comparison areas (%)	Land in riverbank areas (%)	Land in comparison areas (%)	Difference in comparison areas (%)
Fallow	1.3	1.7	0.4	0.3	0.8	0.5
One crop	35.4	44.2	8.8	51.0	37.6	-13.4
Two crop	56.8	51.1	-5.7	41.4	55.7	14.3
Three crop	6.5	2.9	-3.6	7.3	5.9	-1.4

The difference in cropping pattern between two areas in 2000 shows 8.8% more land was used for single cropping, while in 2008 there was considerable reduction of single cropping in the comparison areas, by 13.4%. On the other hand, the percentage of land used for double cropping in a year was less in 2000 in the comparison areas, by 5.7%, which also increased in 2008 by 14.3% compared to the riverbank areas. The difference between the two areas in the practice of three crops a year also reduced over time (see Table 7). This gives the indication of higher adoption of modern technology for agriculture in the comparison areas as well as possibly more profitability from agricultural practices.

It is assumed cropping diversification may help farmers minimize risk arising from natural hazards. However, this has caused major changes in cropping patterns, use of agricultural inputs and management of soil fertility. Cropping intensity, too, has changed: the area under irrigation and high yield variety (HYV) paddy cultivation has increased considerably. Use of inorganic fertilizers increased six times, 1970–90, and the use of pesticides increased about threefold in just one decade, 1982–92 (Rahman and Thapa, 1999).

On the other hand, the area under pulses, oilseeds, fodder and natural inland fisheries declined (FFYP, 1998). Traditional cropping practices, such as mixed cropping, crop rotation and intercropping also disappeared gradually (Hossain and Kashem, 1997). This has led to monocropping and higher dependency on external inputs such as irrigation, inorganic fertilizers and pesticides. Monocropping along with imbalanced use of inorganic fertilizers, pesticides, and intensive land use

Table 8: Irrigation practice in study areas

Irrigation practice in agriculture	2000						2008					
	Riverbank			Comparison			Riverbank			Comparison		
	N	Land ha.	Land (%)	N	Land ha.	Land (%)	N	Land ha.	Land (%)	N	Land ha.	Land (%)
Operated land (ha)	133	71.1	-	217	188.0	-	127	62.1	-	190	129.0	-
Without irrigation		27.7	38.9		77.0	41.0		18.0	29.0		5.0	3.8
Irrigated area		43.4	61.1		111.0	59.0		44.1	71.0		124.0	96.2
Area irrigated by ground water (ha)	235	41.3	95.0	312	98.7	88.9	235	39.0	88.4	312	110.8	89.3
Area irrigated by surface water (ha)	235	2.2	5.0	312	12.3	11.1	235	5.1	11.6	312	13.2	10.7

without application of organic fertilizers have led to deterioration of soil quality and fertility (Hossain and Kashem, 1997; Rahman and Thapa, 1999; Task Force Report, 1991). This trend can be observed throughout the country. For example, total rice production in Bangladesh 1975-76 was 10.32 million tonnes when the country's population was only 79.90 millions and cultivated rice area was 10.32 million ha. However, the country is now producing 27.32 million tonnes on 10.71 mha to feed more than 140 million people (BBS, 2007; DAE, 2007).

This indicates growth of rice production was much faster than the growth of population, though change in cultivable rice area change is not very significant, 1975-2007. This increase in rice production has been possible largely due to the adoption of modern rice varieties on around 73% of the cultivated rice land which contributes to about 85% of the country's total rice production, modern rice cultivation technology, improvement irrigation facilities and applications of fertilizer and pesticides (BBS, 2006).

Irrigation practice

Irrigation practice in the study areas shows the proportion of land cultivated without irrigation reduced significantly, 2000-2008, both in the riverbank and comparison areas, with subsequent increase of land under irrigation coverage. Thus, the irrigated area in the riverbank areas increased from 61% to 71%, whereas in the comparison areas 96% land was cultivated with irrigation (see Table 8). Nevertheless, it is remarkable that the use of groundwater for irrigation in the riverbank areas reduced from 2000 to 2008; the reverse is the case in the comparison areas. Thus, the use of surface water in the comparison areas reduced over time. This indicates that the availability of surface water in the comparison areas might have reduced over time, leading to the increased adoption of agricultural technologies e.g., shallow and deep tubewells.

Poverty

The poverty of households in the study areas has been determined through consideration of household income and expenditure for consumption of minimum 2,100 kcal food per day. The prevalence of poverty in the riverbank areas increased significantly from 2000 to 2008, while in the comparison areas there was only 1% increase in poverty. Thus, higher poverty prevalence is observed in the riverbank areas compared to the comparison areas, both in 2000 and 2008 (see Figure 2, p 56).

The transition of household poverty shows that in the riverbank areas, 34.5% households could never come out of poverty, 2000-2008, whereas in the comparison areas this rate was 29.5%. This indicates higher incidence of chronic poverty in the riverbank areas. In addition, the proportion of households who always remained above the poverty level in the comparison areas was 7.2% higher than in riverbank areas (see Table 9, p 56). Apart from the problem of persistence of poverty in both areas, there were also a considerable proportion of households (13.2% in riverbank areas, 15.7% in comparison areas) who could manage to exit from poverty. However, this improvement was tarnished due to higher proportion of households moving into poverty (21.7% in riverbank areas, 17.0% in comparison areas) compared to those getting rid of poverty. Considering the households moving into and moving out of poverty, the poverty burden in the riverbank areas increased during 2000-2008 compared to that of comparison areas. Nevertheless, if we include the transitory poor with the chronically poor, almost two-thirds of the households experience poverty at some time or other. It is important to maintain stability in the price of staple food for the sake of the economic stability of low-income households, in the context of the sharp impact of the food crisis on poverty (Hossain and Nargis, 2009).

Figure 2: Incidence of poverty in study areas

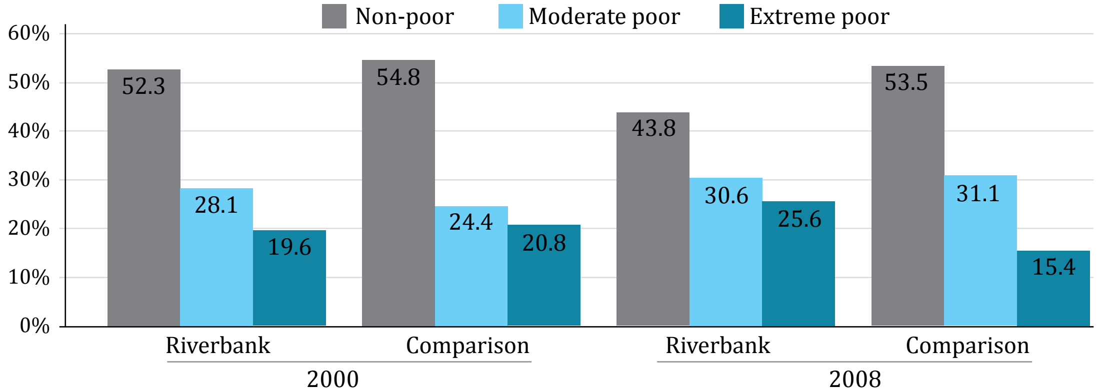

Table 9: Transition of household poverty, 2000-2008

Poverty Status	Riverbank HH (%)	Comparison HH (%)
Always non-poor	30.6	37.8
Non-poor to poor	21.7	17.0
Poor to non-poor	13.2	15.7
Always poor	34.5	29.5
All households	100.0	100.0

Self-perceived economic status

Household were asked what their perception of change in their economic status was in the 20 years from 1998 to 2008. It was found a higher proportion of households in the comparison areas mentioned improvement compared to households in the riverbank areas. Thus, in the riverbank areas higher percentage of households also mentioned deterioration of economic status over time. Since more households could improve economic status in comparison areas, relatively fewer households mentioned unchanged economic situation (see Table 10).

The most significant reasons identified for the improvement of household economic status both in the riverbank and comparison areas were (i) change in agricultural practices—technology adoption and diversification in terms of fish farming, rearing livestock; (ii) involvement in business; (iii) enhanced family capacity—increased number of earning members, earning from service; (iv) remittance; and (v) other opportunities—improved transport system, for example. It is worth mentioning that in the comparison areas more households have identified involvement in business as the prime reason for improvement of economic status than the riverbank areas. Nevertheless, in the riverbank areas enhancement of family capacity was the more frequently mentioned reason for improvement than in the comparison areas (see Table 11).

The households both in the riverbank and comparison areas mentioned increase of family expenditure and reduced family capacity due to losing earning member as the major reasons for deterioration of household economic status during the last 20 years. That apart, loss of agricultural practices in terms of crop loss, bad yield, low market price, flood and drought and land loss were also identified as reasons behind deterioration of economic status (see Table 12).

Food security and per capita income

The food security status of the households in riverbank and comparison areas, in terms of households eating 3 meals a day, showed improvement 2000-2008. Compared to the food security status of 2000, in the riverbank areas 8.9% more households reported they were food-secured in 2008, while the same in the comparison areas was 12.5%. Thus, in both areas households with deficit food reduced remarkably during 2000-2008. However, the overall improvement of food security status in the comparison areas was better than in the riverbank areas (see Table 13, p 58).

The per capita income of all households both in the riverbank and comparison areas increased 2000-2008. Similarly, the per capita income of the chronic poor households in both areas also increased during the same period (see Table 14, p 58v). The increase of per capita income in the comparison areas improved more than the riverbank areas over time. The increase in per capita income of all households as well as the chronic poor households indicates their increased ability to spend for food and ensure food security.

The logit regression analysis of poor households shows a significant relationship with the cultivation of land (ha) and poverty of households, 2000 and 2008. For an increase of cultivating land,

Table 10: Perception of change in economic status in study areas, 1988-2008

Self perceived economic status of the households	Riverbank		Comparison	
	N	Household (%)	N	Household (%)
Improved	113	48.1	183	58.7
Unchanged	68	28.9	72	23.1
Deteriorated	54	23.0	57	18.3
Total	235	100.0	312	100.0

Table 11: Why economic status improved in study areas, 1988-2008

Reasons for improvement	Riverbank HH (%)	Comparison HH (%)
Adoption of agro-technology	21.7	23.0
Enhanced family capacity	24.3	6.6
Business	24.3	41.0
Remittance	8.7	7.1
Engaged in other agriculture (fish/livestock etc.)	5.2	2.2
Other opportunities	15.7	20.2

Table 12: Why economic status deteriorated in study areas, 1988-2008

Reasons for deterioration	River bank HH (%)	Comparison HH (%)
Agricultural loss	16.7	17.5
Increased family expenditure	42.6	47.4
Reduced family capacity	37.0	33.3
Other	3.7	1.8

the probability of households being poor reduces both in 2000 and 2008. Again, households adopting modern technologies for agricultural practices have significantly less probability of being poor. Additionally, household members having warm clothes for winter have significantly less probability of being poor in both areas However, the probability of households being poor have no significant relation with their location in the riverbank areas, found both in 2000 and 2008 (see Table 15).

Findings

Hence, in both riverbank and comparison areas people are predominantly in agriculture 2000-2008, though the average farm size has reduced over time in both areas. Since average family size hasn't shown a major increase, the reasons for reduction of cultivable farm size needs further study, because reduction in farm size might have significant impact on agricultural practice and its profitability.

The riverbank areas are more burdened with poverty over time, compared to the comparison areas. This is evidenced by the calculated poverty prevalence and movement of households into and

Table 13: Food security status of households in the study areas

Food security	2000		2008	
	Riverbank	Comparison	Riverbank	Comparison
HH taken 3 meals a day (%)	86.0	84.6	94.9	97.1
HH deficit of 3 meals a day (%)	14.0	15.4	5.1	2.9
Total	100.0	100.0	100.0	100.0

Table 14: Per capita income of all households in the study areas

Per capita income	Riverbank		Comparison	
	N	Mean	N	Mean
All HHs in 2000 (USD)	235	11016	312	10925
All HHs in 2008* (USD)	235	12396	312	14007
Change in all HHs 2000-2008 (%)	113		128	
Chronic poor HH in 2000 (USD)	81	4422	92	4164
Chronic poor HH in 2008* (USD)	81	5037	92	5430
Change in chronic poor HHs 2000-2008 (%)	114		130	

* 2008 values are at constant prices of 2000

Table 15: Logit regression of household poverty in the study areas

Variable	2000			2008		
	Marginal fixed effect	Standard error	P value	Marginal fixed effect	Standard error	P value
Cultivate land	-0.4000	0.066	0	-0.296	0.060	0.000
HHs adopting agro-technologies	-0.0182	0.059	0.002	-0.223	0.053	0.000
HH members with warm clothes	-0.1580	0.037	0	-0.229	0.045	0.000
HHs in the riverbank areas	0.0370	0.051	0.465	0.161	0.049	0.744

out of poverty. However, though the self-perceived economic status over the longer period (1988-2008) has improved in both areas, relative improvement in the comparison areas has been found better. Apart from enhanced family capacity, earning from businesses and remittance, the households identified adoption of agricultural technology and diversification of agricultural practices as the main reasons for improvement of overall household economic status. Contrary to that, agricultural loss has also been identified as a significant reason for deterioration of household economic status together with increased family expenditure and reduced earning capacity of the households.

Thus, agricultural intensification is inevitable for poverty alleviation and food security in the study areas. This has been observed as well during 2000-2008 both in the riverbank and comparison areas, with the increase of cropping intensity and change of cropping pattern. The cropping intensity, however, has been found to increase more in the comparison areas together with wider irrigation practices, 2000-2008. Nevertheless, though around one-third of the households in the study areas experienced chronic poverty, more than 95% households in 2008 reported to be food-secure. Hence, again the comparison areas have been found in a relatively better situation compared to the riverbank areas. Adoption of technologies for agriculture reduces the chance of household being poor; however, the size of land cultivated also has significant bearing in this regard.

Thus, there is some indication that the households in the riverbank areas might be more vulnerable to poverty and food security. Environmental constraints such as flood, drought, soil salinity and poor land quality limit frequent cultivation of high demanding crops and lower their yield, thereby hindering agricultural growth and rural development (Brookfield, 1972; Brush and Turner, 1987). Under uniform demand levels, the high constraining environments give rise to high technical labour and input-intensive farming systems in which both cropping intensity, land and labour productivities are lower than in low- and medium-constrained environments (Ali, 1987; Padoch, 1985). This is why further research is necessary to reveal the impact of river flow on agricultural practices, poverty and food security from a trans-boundary aspect.

Identifying research issues

This study gives an overall perspective of poverty and food security status of households in the GBM region. The findings show that though the situation of food security has improved over time the riverbank areas are more poverty-burdened. The areas far from the active rivers, however, show a better situation with improvements of cropping pattern, cropping intensity and poverty reduction. Nevertheless, further research is necessary in the context of trans-boundary river flow to depict a relative picture of poverty and food security both upstream and downstream of river flows. Within the existing synergy of agricultural practices and trans-boundary river flows, a number of research issues have been identified. They follow below.

- **Proposed research issue:** Vulnerability assessment of households lying in the river basin.
  Justification: Households in the GBM region are vulnerable to a number of factors, e.g., natural disaster, low income, quality of life. Thus, it is necessary to conduct an overall vulnerability assessment of households with respect to trans-boundary river flows.
- **Proposed research issue:** Reduction of the risks of food insecurity through cropping intensification and change of cropping pattern.
  Justification: It is assumed that due to population increase and reduced farm size, people intensify cropping and change the cropping pattern to increase yield and reduce the risk of food insecurity.

Thus, it is necessary to assess how these factors differ in areas near main rivers and in areas far from the rivers in the GBM region. Thus, it requires studying how the crop yield varies due to crop intensification and change in cropping pattern over time.

- ❑ **Proposed research issue:** Agricultural input changes with proximity to rivers in the GBM region.
  Justification: Agricultural input in terms of seeds, irrigation, inorganic fertilizer, pesticides and so on will differ between areas near to rivers and areas far from rivers. For example, there would be more use of shallow irrigation system in areas near the rivers, while it would need more deep tube wells to use groundwater in areas far from the rivers.

- ❑ **Proposed research issue:** Profitability of agriculture in the GBM agro-ecological zone.
  Justification: The difference in agricultural input will influence the profitability of agricultural practices in the GBM agro-ecological zone. Thus, it is necessary to study the profitability of agricultural practices and reveal its impact on poverty alleviation.

- ❑ **Proposed research issue:** Impact of disasters on agriculture and poverty of households in the GBM region.
  Justification: Disasters like flood might be influenced by the flow of water in the rivers, precipitation and so on, which would cause crop loss and thereby affect agricultural practices, rendering people living nearby the rivers impoverished. Hence, research is needed to measure the vulnerability of agricultural practices induced by disaster.

- ❑ **Proposed research issue:** Poverty in the GBM region is influenced by the proximity of households to rivers.
  Justification: Bangladesh is a country with wide-scale smallholder-intensive subsistence agriculture. Since agricultural productivity is assumed to be influenced by trans-boundary river flows, it is necessary to study its impact on poverty.

- ❑ **Proposed research issue:** Adaptation in agricultural practices for poverty alleviation.
  Justification: People living in the GBM region have adapted themselves with the existing natural, social and economic situation. Agricultural practices have also changed to cope with the changed situation. Thus, it is necessary to identify the existing adaptation measures adopted already and what other potential measures could be adopted for poverty alleviation and ensuring food security.

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Challenges in the GBM region

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Bangladesh is a country of about 162 million people (World Bank, 2011) with an area of 0.148 million sq km (BBS, 2009). It is situated on the northeast of South Asia, bounded by India in the west, north and east, a shorter border with Myanmar in the south-east and by the Bay of Bengal in the south. The country lies in the delta of three mighty rivers, the Ganga, Brahmaputra and Meghna (GBM) and a complex river network of 310 rivers of which 57 are international rivers—54 shared with India and 3 with Myanmar—occupying about 6% of the land area of the country (WARPO, 2000). These three rivers have a combined catchment area of approximately 1.72 million sq km; Bangladesh accounts for only about 8% of this catchment, the rest lying in the upper riparian countries of India, Nepal, Bhutan and China. The country is riverine and by and large flat, with flood plains constituting about 80% of its landmass (Ahmed, 2003). The economy of Bangladesh is essentially agrarian and so critically dependent on water. Bangladesh has a total land area of 14.85 million ha of which 8.44 million ha are under cultivation. Out of total cultivable land, only 4.48 million ha, or 53%, is now under irrigation (Handbook of Agriculture Statistics, 2006).

The agriculture sector is a large contributor to Bangladesh's economy, accounting for around 18.4% of the Gross Domestic Product (Mahbub, 2004). Around 80% of the rural population also depends, directly or indirectly, on agriculture for its livelihood (BBS, 2008).The present cereal requirement of the country is around 32 million tonnes and the country faces an annual deficit of 1.5-2.0 MT per year (Mozaddad Faruque, 2004). The population of the country is expected to rise to 181 million by 2025 and to 224 million by 2050, requiring a substantial increase in foodgrain production, one among many challenges the country faces in an era of increasing climatic change (Mozaddad Faruque, 2004).

The GBM region, one of the world's most populous, has emerged into an intricate mosaic of interactions between man and nature, poverty and prosperity and problems and possibilities. Rapid expansion in agricultural water use is a common theme across these interactions and access to water is central for the livelihoods of the rural poor. Given the diversity of agro-climatic, social and economic conditions in the riparian countries—India, Nepal and Bangladesh—the GBM is clearly one of the most complex river basin systems in the world. Management of GBM water resources presents some formidable challenges, like too much water in the monsoon season and too little water during the dry season (which is true for most of the South Asian trans-boundary rivers) and, therefore, steps must be taken towards integrated management of the GBM's water and land resources in order to ensure the future sustainability of all production and ecosystems in the basin.

It is therefore essential to understand the entire scenario and analyse its impact in terms of various agricultural, social, economic and environmental aspects. Such understanding and studies of impact would help Bangladesh to come to rational discourses with all the riparian countries to safeguard its national and regional interests and also to plan resource management in the future. This study will also examine the water productivity of major cereal crops with a view to assess its impact on food security and poverty.

Water productivity is defined as 'crop production' per unit 'amount of water used' (Molden, 1997). The concept of water productivity in agricultural production systems is focused on producing more food with the same water resources or producing the same amount of food with less water resources. The International Water Management Institute (IWMI) has proposed a change of the nomenclature from '*water use efficiency*' to '*water productivity*'. Water productivity can be further defined in several ways according to the purpose, scale and domain of analysis (Molden *et al*, 2001; Bastiaanssen *et al,* 2003).

The current study will also assess potential regional approaches to increase food security and reduce poverty and also the demand for environmental flow as well as analyse the water resources system in the context of the global climatic changes and under different scenarios of insufficient upstream water flow. As the study is mostly dependent upon the availability of data and information related to Bangladesh and co-riparian countries (India and Nepal), availability of data is one of the top most priority factors for successful analysis of the situation in the basin.

Objectives

The main objective of the study is to identify core issues related to water productivity and poverty, its significance within the GBM. The purpose is also to identify research gaps and needs for future priority joint research areas. The specific objectives pursued through the study include:

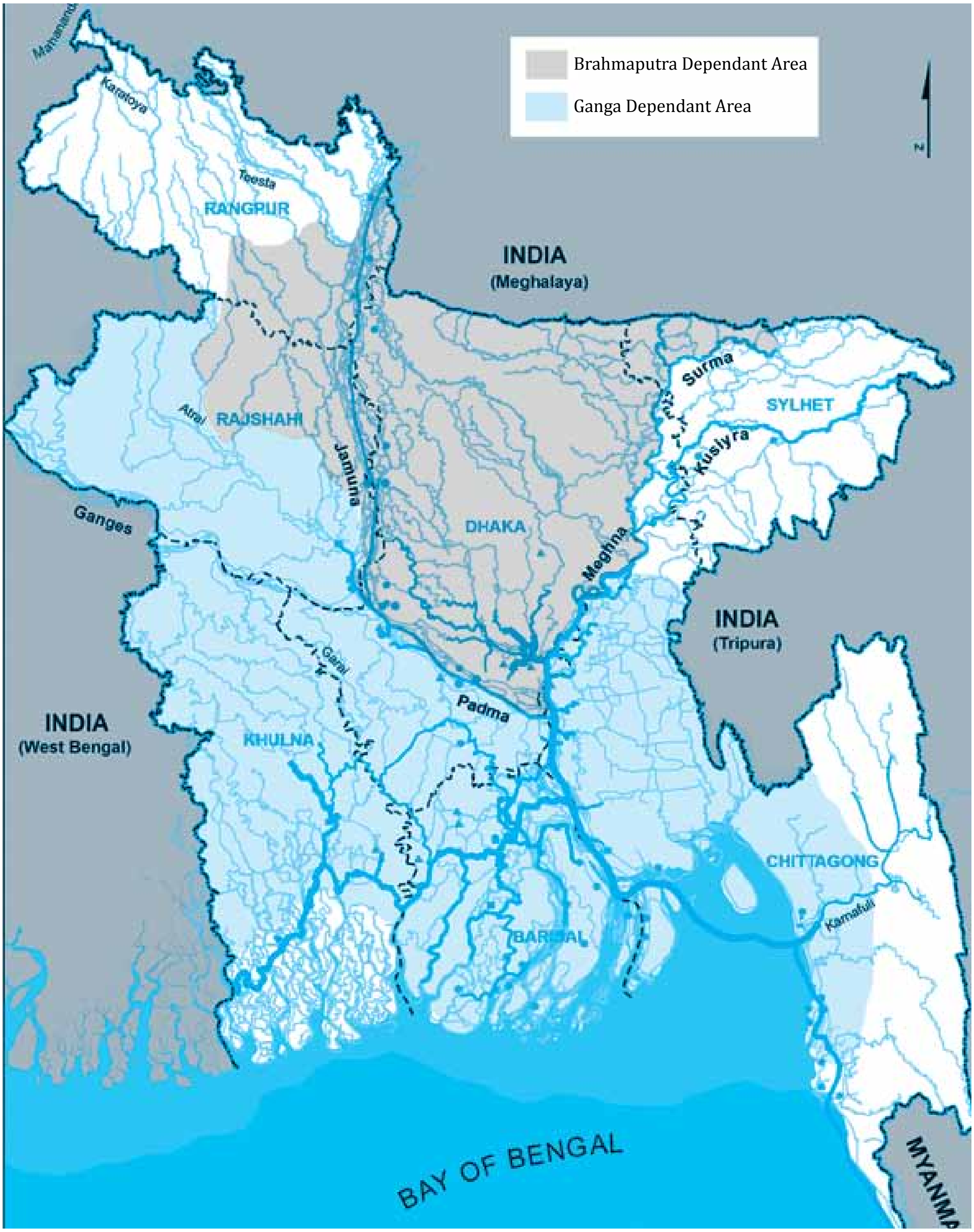
- Investigation of present status of water productivity, poverty, livelihood of GBM basin;
- Assessment of water requirements for agriculture, water quality and salinity control for Bangladesh based on available secondary information and literature review; and
- Socio-economic study on probable impact on the society, culture and overall livelihood in the country due to reduced availability of water.

The GBM scenario

Before going into further details, we would like to define the Ganges Dependent Area (GDA), which is the area directly influenced by the Ganga river in terms of historic linkages, current direct impact and potentially commanded land (see Map 1). Also, impact with respect to agricultural production, flood and environmental risk will be determined. The GDA encompasses the whole of the southwest region of Bangladesh (with the exception of Bhola Island), plus a strip of land along the left banks of the Ganga and the Padma, which relates directly to these two rivers. For water resource planning, Bangladesh has been divided into eight regions based on hydrological conditions.

The Brahmaputra river splits by its two branches: the much larger branch continues due south as the river Jamuna (Jomuna) and flows into the Lower Ganga, locally called river Padma (Pôdda), while the older branch curves southeast as the lower Brahmaputra and flows into the river Meghna.

Map 1: The GBM: Ganga Dependant Area (GDA) and Brahmaputra Dependant Area (BDA)



Source: CEGIS

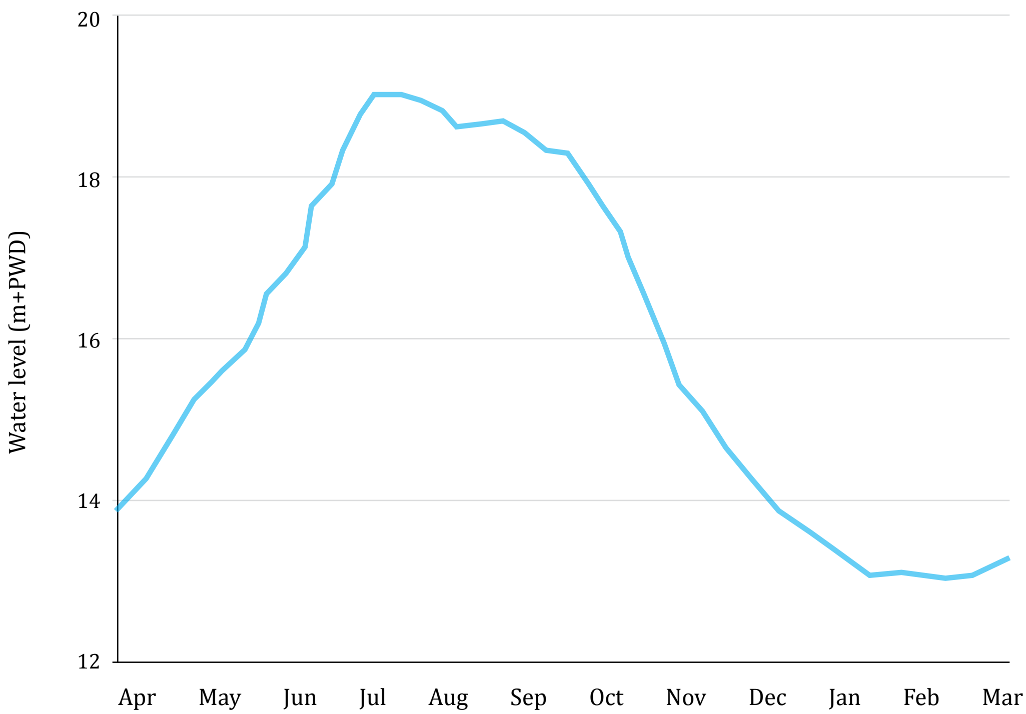
The peak level of the Brahmaputra river is between July and August. The variation of annual average water level at Bahadurabad is about 6.5 m (see Figure 1). The average flood level and low water level for the period 1965-2005 are 19.8 m. and 13.2 m (benchmark established by the Public Work Department) respectively. The average water level slopes in the upstream and in the downstream of the Brahmaputra river are 8.5 and 6.5 cm/km respectively (CEGIS, 2008). The gradient of the river in Bangladesh is 0.000077, decreasing to 0.00005 near the confluence with the Ganga. The river has a total suspended load discharge of about 725 million tons per annum (CEGIS, 2008).

Water demand and availability

Water becomes a really scarce resource in Bangladesh during the dry months of the year (Feb-May). Maximum water demand occurs in March, because dry season paddy comes into the flowering stage. Any water stress significantly reduces yield. It may be mentioned here that dry season paddy is the largest contributor to the grain basket of the country.

The first assessment of availability and demand of water resources in the critical month of March was made by the Master Plan Organisation (MPO, now Water Resources Planning Organisation) and presented in the National Water Plan prepared in 1986. In 1999 the MPO updated the National Water Plan together with the demand and supply of water. Gross water demand was based on the

Figure 1: Average water level hydrograph of Jamuna at Bahadurabad (1976-2005)



irrigation requirement, salinity control in the estuaries, riverine fisheries, inland navigation, fisheries and salinity control and domestic and industrial uses. There are about 8.42 million ha of cultivable land, of which about 6.9 mha of agricultural land can be brought under irrigation at full development by the year 2018 (Ahmed, 2001). The total water requirement for the dry season has been estimated at 25,697 million cubic metre (m cum) which includes 14,209 m cum for agriculture, 9,910 m cum for navigation and 170 m cum for domestic and industrial use. The total water supply in the wet season is 14,209 m cum—5,360 m cum of groundwater, 6,390 m cum from regional rivers, beels and haors and 11,740 m cum from main rivers (Ahmed, 2001). Agricultural water requirement is 58.6% of the total; navigation, salinity control and fisheries demand 40.7% and domestic and industrial need accounts for only 0.7% of total demand. For these requirements, 77.2% is expected to be provided by surface water and the balance 22.8% is expected to come from groundwater (Ahmed, 2001).

The coastal area includes the delta region of the Ganga-Padma river and the estuary of the lower Meghna, with its numerous islands. The coastline has changed little along the western part, but has accreted on the seaward island shores to the east. Apart from the Sundarbans, and plantations on new accreted land, the coastal and estuarine areas have been cleared for agriculture and are heavily populated. To provide flood protection for agriculture, a series of coastal embankments were constructed in the 1960s and 1970s under the Coastal Embankment Project (CEP). The CEP polders provided the means to enhance crop production through security from flooding, saline intrusion and soil leaching (ICRD, WARPO, 2005).

Poverty profile and hotspots

Bangladesh is described as one of the poorest countries in the world with a GDP per capita of US$1,600 per annum and a Human Development Index rank of 139 out of 178 countries in 2009 (UNDP, 2009). Based on a poverty line constructed as less than US$1 per day per person, 29% of the population are found as income-poor, which increases to 78% if the poverty line is raised to less than US$2 per day per person (UNDP, 2009). Based on a poverty line measured by the direct calorie intake method of less than 2,122 kcal per person per day, it is found that 44.3% of the total population of Bangladesh or 55.9 million were “absolute” poor in 2002; the corresponding figure for rural areas is 42.3% or 42.6 million (BBS, 2002). The upper poverty line is constructed at Tk 690 in 2000 for rural areas, whereas the lower poverty line is estimated as Tk 586 for the same (BBS, 2002). The upper poverty line shows 49.8% of the total population and 53.1% of the rural population are income poor (BBS, 2002). Thus, more than half the rural population in Bangladesh is consumption-poor.

Poverty and hunger: situation and trend analysis

Experience of the last few decades indicates that, on average, economic growth in Bangladesh has been associated with reduction in income poverty and faster reduction of non-income poverty. Poverty reduction, however, has not proceeded at the same rate with growth of income in different sub-periods. The variation in the rate of poverty reduction in different sub-periods provides some evidence that growth can be more or less pro-poor depending on other factors. The need for pro-poor growth strategy emerges out of the fact that poverty is not only disgraceful to the poor but also a barrier to development since it limits economic demand, squeezes human capability and hampers social cohesion and political stability in society. A pro-poor growth strategy is thus a precondition for more sustainable and stable development of the society, especially where there is enormous magnitude of poverty, as in Bangladesh.

Table 1. Population below national poverty line (%)

Year	Rural	Urban	National
1990	61.20	44.90	58.80
1995	55.30	29.50	51.00
2000	52.30	35.20	48.90
2005	43.80	28.40	40.00
2007	42.30	27.60	38.66

Source: BBS, 2007

Population below national poverty line

The proportion of population below national poverty line in 2005 was 40%. In 2007 it reduced approximately 1.5%, to 38.66%.The trend observed in urban and rural poverty was similar (see Table 1). The poverty situation varied over time as well as between urban and rural areas. The rate of poverty reduction shows that the trend was higher during 2000-05; also, in the same period, the reduction rate was higher in urban areas. The plausible reason for higher rate of reduction in poverty, 2000-05, was steady agricultural growth and no natural hazards (ADB, 2005). On the other hand, the flood in 1997 and 1998 seriously affected human life and damage to crops and animals was significant. Trade liberalization in the agricultural input market was completed by the end of the 1990s and cheaper agricultural machinery was introduced in Bangladesh, which ultimately influenced higher economic growth and so poverty reduction in rural areas during 2000-05. The rate of poverty reduction was also higher in urban areas due to higher employment opportunities created by robust growth in the agriculture sector (ADB, 2005).

Poverty: spatial variation

Administratively the country is divided into seven divisions (Rangpur has recently been declared a new division. But currently, no separate data are available of this newly-formed division, split from the Rajshahi division). There is also a regional variation in the incidence of poverty: there were large variations of poverty among the divisions, as observed in the data related to the period 2000-2005 (see Table 2). For instance, it was observed that Rajshahi and Barisal were significantly below the national poverty level. It means that these areas remained undeveloped; also, within the divisions the rural and urban households also showed significant difference in poverty. In urban areas the proportion of poverty was 28.40% in 2005 against 35.20% in 2000; a high degree but still lower than poverty in the rural areas, where the poverty level was 43.80% in 2005 and 52.30% in 2000 (see Table 2).The rate of reduction in poverty, 2000-05, was higher in Dhaka, Chittagong and Sylhet while the rural people of Rajshahi division migrated to urban slums and became poorer due to less opportunity to work in the rural areas in the *monga* season (Sebastian Zug, 2006).

Poverty hotspots

The saline coastal areas of the south, the flush flood-prone natural deep wetlands (Haor) of the northeast and the river erosion-prone central part of the country can be considered as the principal poverty hotspots of the country (see Map 2, p 72). Acute poverty (diet) in these areas can be directly attributed to water-related events (World Bank, 2008). In the south, salinity is increasingly intruding inland due to significant reduction of river flows, especially in the dry season. This is also adversely impacting the bio-diversity of the Sundarbans (Gain *et al*, 2008), a UNESCO-designated world heritage site. The increased salinity reduces crop yield and thus the income of the farmers. The same population also suffers natural disasters like cyclones and tidal surges. On the ground, the situation has become so difficult that shortage of food and drinking water will threaten the very existence of the population in those areas if the situation is not addressed on a priority basis. This should include development of salt-tolerant crop varieties and construction of large surface water reservoir for domestic water supply as well as for irrigation.

Rice, the one and only cultivated crop in the Haor areas, is destroyed by flash floods coming from the upper riparian countries. As these incidents are on the increase, population in these areas goes through chronic poverty (diet) for indefinite periods (Ambar Narayan *et al*, 2007).

The populations living in the river banks in the central part of the country are subject to repeated floods and river bank erosion and in many cases lose their agricultural land and homesteads. In extreme cases, people of affected areas migrate to urban areas and lead a life of perennial poverty. Bangladesh on its own has been able to reduce river bank erosion from 10,000 ha per year to 6,000 ha per year in the Jamuna river (BWDB, 2011). It may be pointed out that the net loss of land due to erosion is likely to be much less, since river erosion is generally accompanied by formation of new lands (char) in places close to eroded areas. Almost all poverty hotspots in Bangladesh have resulted directly from water-related events and the situation can only addressed by concentrated efforts of all the riparian countries, especially the upper riparians.

Poverty levels of all the three spots can be effectively dealt with if a regional programme on water management can be adapted and implemented. Construction of dams and/or storage reservoirs in the up-stream countries, especially in Nepal, will help in reducing flood and river bank erosion in the wet season and augment flow in the dry season preventing salinity from entering further into the inland. This is expected to help population in the dependent areas to avoid damages to crops and other related elements in the agricultural production system, such as livestock and fishery. Due to augmentation of flow in the dry season, groundwater will also be recharged, increasing both the irrigated area and crop production.

Table 2. Population below national income poverty line (%)

Divisions	2000			2005		
	National	Rural	Urban	National	Rural	Urban
Dhaka	46.70	55.90	28.20	32.00	39.00	20.20
Chittagong	45.70	46.30	44.20	34.00	36.00	27.80
Sylhet	42.40	41.90	49.60	33.80	36.10	18.60
Barisal	53.10	55.10	32.00	52.00	54.10	40.40
Khulna	45.10	46.40	38.50	45.70	46.50	43.20
Rajshahi	56.70	58.50	44.50	51.20	52.30	45.20
Bangladesh	48.90	52.30	35.20	40.00	43.80	28.40

Source: Bangladesh Economic Review, 2007

Foodgrain production and issues of food security

Foodgrain production, particularly rice production, has doubled in the last two decades (Rahman *et al*, 2009) with the use of Green Revolution technology (high yielding varieties, fertilizer, irrigation and pesticides) coupled with growth of institutional infrastructure and a positive shift in public policy and market forces. As a major staple, rice occupies 71% of the gross cropped area and accounts for over 94% of foodgrain production (Hossain *et al*, 2005). Its contribution to total per capita calorie and protein intake is 74%. Rice, thus, occupies the centre stage of food security and continues to draw the major attention of the government for further increasing production (Hossain *et al*, 2005).

Though rice production continues to increase, wheat production—the second largest cereal crop—is showing a significant declining trend in recent years. Remarkable progress has been made

Map 1: Poverty hotspots, Bangladesh

in rice production during the last ten years. In 1994-95, rice production was 16.83 million tons (BBS, 2002), steadily increasing to 26.19 million tons in 2003-04 (see Table 3, p 74). Rice production, 2004-05, was 25.16 million tons. Wheat production also increased from 1.25 million tons in 1994-95 to 1.91 million tons in 1998- 99 (BBS, 2002). It then started declining, coming down to 0.97 million tons in 2004-05 (see Table 4, p 74). Rice constitutes 94% of all cereals produced in the country. Thus, maintaining production increase will be the cornerstone of food security, since the production of the other principal cereal, wheat, has decreased significantly in recent years.

Foodgrain production: spatial variation

Let us first look at rice. Rice is cultivated on about 11.28 million ha, with a production of 31 million tonnes in 2008-09. In 2001-02, the area and production were 10.67 million ha and 24.3 million tones respectively. During this period, i.e. 2001 to 2009, area under rice cultivation increased by 5% but the yield increased by around 14% (see Table 5, p 75). Reasons behind this may be the modern technology of production and development of public policy and market forces (Rahman *et al,* 2009).

There has been a very slight positive change in the area and production of rice in Dhaka and Barishal divisions. In Chittagong and Sylhet divisions, however, a near stagnant or a decreasing trend can be seen. This can be attributed to a) frequent occurrence of natural disasters like Sidr, Aila in the coastal region (Jayanta Kumar Basak, 2010); b) flash floods in the chars and haors; and c) lack of suitable varieties for upland and deepwater rice ecosystems (Nguu Van Nguyen, 2007). The increase in production of rice in Khulna and Rajshahi divisions can be attributed primarily to the increase in cropped area. Increasing rice production further is a formidable task since there is very little scope for horizontal expansion of the rice area due to the gradual reduction of cultivated land as a result of diverting its uses for houses, roads, industries and urbanization (Bhuiyan & Karim, 1999). It can be observed that average yield of rice is very low (see table 5, p 75). In addition to conventional reason like traditional management of the production system soil fertility, especially low organic matter content (≤ 1.5%), is also major contributors to low yields.

Now, let us look at wheat. The latest figures from the government put wheat production levels for 2008/9 at 0.84 million tonnes, decreased from 1.6 million tonnes in 2001/02. It has been observed that though the area planted by wheat has decreased by 29.5% (see Table 4, p 74) compared to 2001/02, the yield has increased by 5%. Although the reasons for the near-100% reduction in area are debatable, two factors are frequently cited as having contributed to the deceleration. First, limited access to irrigation; second, in the late 1980s, when subsidies were withdrawn from many inputs, sudden sharp increases in input prices may have led wheat growers to cut back on their use.

The highest production of wheat can be observed in Rajshahi division (Wheat production in Rangpur division is also higher, but presently no separate data are available of the division): in 2001-2002, it was 986,290 metric tonnes, but in following years production decreased gradually, nearly halving by 2008-2009 (489,857 metric tonnes). Similar trend is observed in the rest of the divisions. Wheat is a quirky plant. Temperature is a very important factor for wheat production. Erratic rainfall coupled with late onset of winter has led to decrease in Rabi sowing area and wheat acreage. Water scarcity resulting from reduced flow in the rivers, coupled with warm weather, has affected the acreage of wheat. All these reasons have become a major concern for decreasing production of wheat in Bangladesh.

The third cereal of importance in Bangladesh is maize; its production is significantly increasing. From 1995-96 to 1998-1999, the annual rate of change of area, production and yield of maize were almost same (see Table 6, p 76). But after 2001, the area and production of maize increased dramatically. During 1995-96 about 2.8 thousand hectares of land was under cultivation of maize and the yield was 1.1 t/ha. In 2000-01 yield doubled, compared to 1995-96, and in 2008-09 yield increased five times than that in 1995-96. This has resulted from large scale use of improved seeds including hybrids, agrochemical and irrigation and a growing market for it. In Bangladesh demand for maize is rising as human food and also for the poultry and fish industries. This has led to a trend away from traditional rice-rice and rice-wheat cropping systems and toward rice-maize systems.

Food security

The prevalence of undernourishment, according to the latest FAO report, reveals 30% people are still undernourished in Bangladesh. Foodgrain is more available in good harvest years; still, Bangladesh

Table 3. Rice in Bangladesh, 2004-2009

Division		Dhaka	Chittagong	Sylhet	Barisal	Khulna	Rajshahi	Total
2004-05	Area	2516	1785	796	1035	1260	3114	10372
	Prod.	6344	4390	1758	1625	3352	3796	25157
2005-06	Area	2536	1550	854	1028	1638	3241	105334
	Prod.	6681	3860	1951	1786	3919	8715	26530
2006-07	Area	2573	1334	843	974	1330	3339	10584
	Prod.	6842	3772	1867	1653	3688	9496	27318
2007-08	Area	2446	1513	801	940	1416	3354	10578
	Prod.	7285	3974	2096	1601	3497	10269	28931
2008-09	Area	2618	1067	875	1109	1522	3549	11284
	Prod.	7709	3118	2204	2056	4225	10851	31317

Note: Area is in ’000 hectares; production is in ’000 metric tonnes. Source: Agriculture Statistics, BBS, 2009

Table 4. Wheat in Bangladesh, 2001-2009

Division		Dhaka	Chittagong	Sylhet	Barisal	Khulna	Rajshahi	Total
2001-02	Area	16696	45514	3619	6943	9746	460825	543342
	Prod.	306260	79900	7620	11540	223150	986290	1605760
2003-04	Area	100785	36109	2623	4101	83024	344040	570682
	Prod.	189740	67630	5350	7490	181690	752550	1253380
2004-05	Area	84653	31665	2522	4009	71062	337022	530933
	Prod.	147327	50412	4519	5558	104353	634335	975985
2005-06	Area	76846	29398	1721	3013	64866	285211	461046
	Prod.	109836	35663	2373	4022	114217	439084	735462
2006-07	Area	66291	19591	870	3723	56990	311096	458561
	Prod.	104928	29089	1427	5833	110200	465967	736893

Note: Area is in hectares; production is in metric tonnes. Source: Agriculture Statistics, BBS, 2009 as a whole has a very low level of nutrition. This means many households and individuals do not eat a balanced, nutritious diet, even in good years. According to the World Bank, approximately 33 million of the 150 million people in Bangladesh cannot afford an average daily intake of more than 1,800 kilocalories—the minimum standard for nutrition as set by the World Food Program. For people in most developing countries, the daily calorie intake average is 2,828. In Bangladesh, that average is only 2,190 (Amin and Farid, 2005).

Food security at household level is closely linked with poverty. These poverty and food security problems are massive, with approximately half of the population lacking the resources to acquire enough food and consequently remaining below the poverty line. Two approaches are generally used for measuring the incidence of poverty: direct calorie intake (DCI) method and cost of basic need (CBN) method. The Bangladesh Bureau of Statistics (BBS) has estimated the extent of poverty using the DCI method through its successive Household Expenditure Surveys (HESs).This is conducted every five years.

On a national scale, Bangladesh has obtained food through domestic production, imports and food aid. The Household Food Security Nutrition Assessment, 2008-2009 reported that population living in Rajshahi (consumption rate in Rangpur division is also poor, but presently no separate data are available of this newly-formed division, split from the Rajshahi division) and Barishal divisions have lower food consumption scores in comparison with other divisions (see Table 7, p 77).

Though cropped area has increased, yet the country is short in food production by 1.5-2 million tonnes. It is also observed (see Table 7, p 77) that rural areas (27%) are more vulnerable in terms of food insecurity than the urban (17%). While poverty is an overall denominator of this food insecurity in the country, the additional intensifiers are disability (gender, age, and physical challenge) and

Table 5. Rice and wheat yield, 2001-2009

Crop/Year	Dhaka	Chittagong	Sylhet	Barishal	Khulna	Rajshahi	Average
2001¬2002	2.3	2.4	2.1	1.6	2.9	2.4	2.3
2002¬2003	2.4	2.4	2.1	1.6	2.5	2.4	2.2
2003¬2004	2.6	2.6	2.2	1.7	2.7	2.5	2.3
2004¬2005	2.5	2.5	2.2	1.6	2.7	1.2	2.1
2005¬2006	2.6	2.5	2.3	1.7	2.4	2.7	2.4
2006¬2007	2.7	2.8	2.2	1.6	2.8	2.8	2.5
2007¬2008	2.9	2.6	2.6	1.7	2.5	3.1	2.6
2008¬2009	2.9	2.9	2.5	1.9	2.8	3.1	2.7
2001¬2002	1.4	1.8	2.1	1.7	2.3	2.1	1.9
2003¬2004	2.0	1.6	2.0	1.8	2.2	2.2	1.9
2004¬2005	1.7	1.6	1.8	1.4	1.5	1.9	1.7
2005¬2006	1.4	1.2	1.4	1.3	1.8	1.5	1.4
2006¬2007	1.6	1.5	1.6	1.6	1.9	1.5	1.4
2007¬2008	1.9	1.5	2.0	2.0	2.4	2.1	2.0
2008¬2009	2.1	1.5	1.9	2.2	2.3	2.2	2.0

Note: Yield is in tonnes per hectare. Source: BBS, 2009

Table 6: Maize in Bangladesh, 1995-2009

Year	Area	Production	Yield
1995-1996	2.8	3	1.1
1996-1997	2.4	3	1.3
1997-1998	2.4	3	1.3
1998-1999	2.8	3	1.1
1999-2000	3.2	4	1.3
2000-2001	4.4	10	2.3
2001-2002	19.6	64	3.3
2002-2003	28.8	117	4.2
2003-2004	49.6	241	4.9
2004-2005	66	356	5.4
2005-2006	97.2	522	5.4
2006-2007	149.2	902	6.0
2007-2008	221.2	1346	6.1
2008-2009	126.8	730	5.6

Note: Area is in '000 hectares; production is in '000 tonnes; yield is in tonnes/hectare. Source: Agricultural Statistics, BBS, Statistical Yearbook of Bangladesh, 2009

location (disaster proneness, access to the market etc) as well as other aspects related to utilization (education, awareness, cultural practices etc) (Mozumder *et al*, 2009).

Water productivity

Water productivity of all major cereals in the divisions continues to be very low (FAO standard; 1 cu m of water should produce 1 kg of rice). But water productivity of rice and wheat continues to be very low (see Table 8, p 78). Water productivity of rice is even lower than wheat because of very low per unit area yield and use of flood irrigation. But in wheat it is primarily due to low yield.

Similar situation may also prevail in other countries of GBM region. Bangladesh is attempting to increase water productivity by both increased yield per unit area and reduction in irrigation water. With International Rice Research Institute (IRRI), Bangladesh Rice Research Institute (BRRI) has developed a water-saving irrigation application technology called AWAD (Alternate wetting drying) where 40% water is saved without sacrificing yield (IRRI, 2010). This technology is now being field-tested. If successful, the results should be shared with regional countries. Similar successful technologies for increased water productivity developed in the other countries may also be shared.

If the water productivity is low in all the riparian countries, a joint regional program shall have to be launched to improve it and a goal may be set to increase this by at least 5% from the present level (at least in Bangladesh. For other countries the target increase will depend on their water productivity value). It may be mentioned here that increase in cereal production, especially rice and wheat, will have significant impact in the reduction of poverty and increase in food security.

Table 7. Food Insecurity status, Bangladesh

Category	Area	% Food Insecurity
National	Average	25
	Urban	17
	Rural	27
Divisions	Dhaka	20
	Chittagong	25
	Sylhet	24
	Barishal	26
	Khulna	25
	Rajshahi	31

Source: Household Food Security Nutrition Assessment, 2008-2009

Access to irrigation

The major portion of the fabulously fertile agricultural land in Bangladesh occurs on the vast floodplains of the Bengal delta formed by the deposition of sediments from the enormous rivers Ganga, Brahmaputra, the Meghna (GBM) and the Teesta—all of which originate outside the country. As has been mentioned earlier, the combined total catchments area of these major river systems is about 174 million sq km, of which only 8% lies within Bangladesh territory (Karim and Iqbal, 2001). For this reason, Bangladesh has very little control over the huge quantity of surface water of this vast catchment area that flows through these rivers to the Bay of Bengal (Karim and Iqbal, 2001).

In Bangladesh, agriculture contributes about 18.4% to GDP. About 77% of total irrigated area is under groundwater irrigation (BBS, 2006).There are two major sources of irrigation in Bangladesh—surface water and groundwater. Low Lift pump (LLP), Canal and traditional equipment (Dhoon and swing basket) are used as means for lifting surface water for irrigation while Deep Tube Wells or DTWs (BER, 2007), Shallow Tube Wells or STWs (BBS, 2008) and Hand Tube Wells are used for groundwater irrigation. Before the 1970s, irrigation mainly depended on surface sources; in the mid-seventies the government initiated groundwater irrigation with DTW projects. But government soon shifted to STW because of its suitability to the socio-economic status of the farmers (less investment cost, small land holdings, availability in the market, withdrawing restriction on import and STWs spacing) and, by 2008, STWs commanded 62% of total irrigated area (BBS, 2008).

From the early 1970s irrigation coverage increased steadily, to 6.058 million ha by 2007-08 (see Table 9, p 79). The irrigation potential is estimated at 7.55 million ha (Ernest, 2007). It is still possible to expand irrigated area by 28%, going by to irrigation potential. At present groundwater contributes 9.36% of total irrigated area in Bangladesh (BBS, 2009). The application of groundwater irrigation increased with the introduction of High Yielding Variety (HYV) seeds to meet the food requirements of a growing population (BER, 2006). It may be noted thatthe yield potential of the existing HYV rice is more than 4 metric tonnes/ha, whereas the average yield realized by the majority of farmers is less than 3 mt/ha (Talukder, 2008). Thus, on-farm research is very important to reduce the yield gap. If similar situation exists in other riparian countries collaborative research may be initiated to address the issue.

Table 8. Water productivity, 2009

	Water Productivity	
	Rice	Wheat
Dhaka	0.2	0.4
Chittagong	0.2	0.3
Sylhet	0.2	0.3
Barishal	0.2	0.4
Khulna	0.2	0.4
Rajshahi	0.3	0.4
Average	0.2	0.4

Note: Seed to seed water requirement of rice is 1200 mm; that of wheat is 600 mm.
Source: BBS, 2009:

Land use

Land use in Bangladesh has evolved through natural forces as well as human needs. Cultivated land, forestland and settlements and homesteads are the major land use types in Bangladesh (see Table 10, p 80). With growing population and their increasing needs in various sectors, land use patterns are undergoing a qualitative change in which the area under net cropped land and forest land is gradually shrinking. A large part of forest land is now under different types of non-forest land use, for example, as shifting agriculture, illegal occupation for homestead, shrimp culture and so on.

Another important feature of land use in Bangladesh at present is the small area (only 3%) of fallow land and a cropping intensity of nearly 200% (BBS, 2009), indicating that land in this country is not allowed sufficient rest to regain natural biophysical properties vitally important for good soil health. It is imperative to maintain good biophysical condition of soil for sustained agricultural production.

The land area under the head 'uncultivated area' includes mainly urban and rural settlements and industrial lands cover around one-fourth of the total national land area (see Table 10, p 80). Area covered by homestead is around 9.3% of the total land area and is characterised by intensively planted trees but is not efficiently managed (Bashar, 2001). The homesteads represent the agro-forestry model in rural Bangladesh. In the face of diminishing forest reserves, homestead agro-forestry is playing an important role in mitigating the needs of rural masses. These rural homesteads are often uncared and underutilised and can be made more productive through application of better technology and management. Well-planned marginal land management combining woody perennials with vegetables, fruits, livestock, poultry, fish and farming in tune with the farmers' need will lead to sustainable livelihoods.

Environmental hotspots and vulnerability

The geographical setting as well as man-made activities has made the country vulnerable to various natural disasters. These natural calamities occasionally cause drastic crop failures along with

Table 9. Modes of irrigation, 2001-2008

Category		2001-2002	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008
Groundwater		4062400	4222800	4446800	4446800	5109600	5412800	5673200
		89.4%	90.4%	91.1%	89.4%	92.3%	93.0%	93.6%
Canals		160800	144000	143600	-	-	-	-
		3.5%	3.1%	2.9%				
Traditional*		320000	303600	287200	482800	427200	414800	385200
		7.0%	6.5%	5.8%	9.7%	7.7%	7.1%	6.3%
Total		4543200	4670400	4877600	4976400	5536800	5827600	6058000

Note: Area is in hectares. *includes doons, swing baskets and others. Source: Agriculture Statistics Wing, BBS, 2009

huge loss of lives and properties. In some cases the natural calamities influence land use and land management practices. Annual flooding in Bangladesh is a regular feature during the peak monsoon season, when land remains inundated for varying depths and duration; then, the land temporarily goes out of control of man. The usual assumption is that the coastal area and the large river delta will be the most severely affected areas while the elevated parts in the south-east of Bangladesh are generally considered to be far less affected. Only more recently—largely due to the catastrophic landslides in Chittagong in June 2007—has it been recognized that the Chittagong Hill Tracts (CHT) may also be affected significantly by climate change-induced disasters (Bernhard G. Gunter *et al*, 2008). While flash floods and landslides in the CHT are related to mostly man-made soil erosion and deforestation, the frequency and severity of such disasters is likely to increase sharply in the coastal areas of Chittagong district due to climate-change induced increases in precipitation and storm surges.

Cyclones and tidal surges

Tropical cyclones, the most devastating natural calamities in terms of toll on human lives, originate near the equatorial region of the Bay of Bengal and slowly move northward towards the offshore areas of Bangladesh. Colossal loss of lives of human and livestock along with the loss of agricultural crops are common. The water surges that accompany these cyclones often sweep the coastal areas with saline water causing the soils to become temporarily saline and rendering them completely unsuitable for agricultural use.

Riverbank erosion

In Bangladesh, riverbank erosion is caused mainly by strong river current triggered by channel diversion especially during the rainy season when the river water is heavily laden with suspended materials. About 1.7 mha of floodplain areas of Bangladesh are prone to riverbank erosion. The loss of land due to riverbank erosion is highest in the Brahmaputra-Jamuna basin, where the erosion rate is estimated to be between 139-358 hectares per year (Chowdhury, 2000). Riverbank erosion causes not only quantitative loss of the land, but also severely affect the socioeconomic condition of million of the affected owners. The Bangladesh government has already made 468 km embankments to protect river banks from erosion (Hye, 2007).

Table 10. Land utilisation in Bangladesh, 2009

Divisions	Total	Forest	Uncultivated	Cropped
Chittagong	7515	3856	2009	4606
Dhaka	7705	259	2721	8472
Sylhet	3113	191	1331	2293
Barishal	3285	646	906	2755
Khulna	5546	1426	1531	4666
Rajshahi	8515	42	2485	11130
Total	35679	6420	1098	33922
		18%	30%	95%

Note: Area is in ’000 hectares. Source: Statistical Year Book of Bangladesh, 2009

Deforestation

Deforestation is a serious environmental concern in Bangladesh, which is caused by industrialization, rapid urbanization, high population pressure, jhum cultivation and shrimp culture. Deforestation is becoming more and more an acute problem with time and is threatening the destruction of the tropical rainforest of the country at an alarming rate. The actual tree cover in the forest area has now been reduced to only 6% of the total land area of the country (Huda and Roy, 2000). Another startling fact is that about 50% of the forest of the country has been destroyed during the last 20 years. Such a drastic depletion of forest cover is now blamed for the increase of drought in of the central part of the Barind tract in northwestern Bangladesh (Huda and Roy, 2000).

Sedimentation

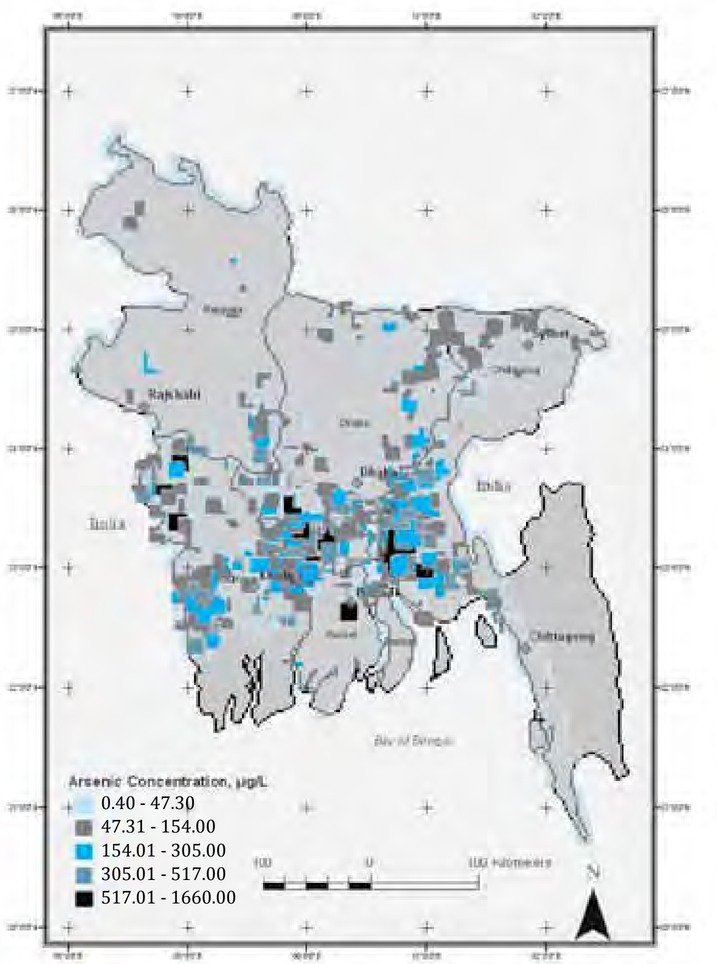
Sedimentation, drainage congestion and loss of wetlands contribute to infertile sand or coarse sediments in the Brahmaputra basin of Bangladesh and reduce the productivity of the topsoil. In future, climate change-induced higher sedimentation rates will have serious social and economic implications (World Bank 2001). Land types in the floodplain areas of Bangladesh are changing as a result of rural infrastructure development (USAID, 1991). Moreover, with the fall of general flood level in the Brahmaputra and Ganga floodplains, the Medium Low Land (MLL) has changed to Medium High Land (MHL) (Karim and Iqbal, 2001). Nearly 1 billion tonnes of sediments are carried into Bangladesh from upper catchment every year, causing severe siltation of the rivers, raising river beds and increasing erosion (BWDB, 2011). Collaborative effort will be needed to address this issue.

Arsenic contamination

Arsenic contamination is increasingly becoming a major threat to both municipal water supply and agricultural production. It has been identified that a vast area in the lower Ganga delta, the Jamuna, the Padma and the lower Meghna river alluvia has emerged as the single largest arsenic-contaminated region in the world. The people of this vast region are continuously exposed to arsenic toxicity through drinking arsenic-contaminated groundwater, causing serious health hazards. Using arsenic-polluted water for irrigation potentially is risky, as this poisonous element will ultimately enter the food chain. Latest information indicates that out of 64 districts in Bangladesh, 61 districts have arsenic in their groundwater; here live more than 65% of the country's population (Chowdhury, 2000). People in 59 districts comprising 126,134 sq km of Bangladesh are suffering due to arsenic contamination in drinking water. Seventy-five million people are at risk and 24 million are potentially exposed to arsenic contamination (Safiuddin & Karim, 2001).

Arsenic distribution is distinct, with the highest concentrations in the south and south-east and the lowest in the north and north-west of Bangladesh. A large variation in the average arsenic concentration is also found in each administrative division (see Map 3). All divisions contain at least one spot which exceeds the Bangladesh standard of 50 ppb. The coastal region is highly vulnerable to arsenic contamination. Evidence suggests high levels of arsenic in irrigation water could degrade soils, reduce yield and find its way in to the food chain. People may be exposed to arsenic not only through drinking water, but indirectly through food crops irrigated by contaminated groundwater. Of the 6.05 mha of land under irrigation, about 2.4 mha are irrigated by shallow tube wells. Approximately 95%

Map 3: Arsenic contamination in Bangladesh



Source: Ibrahim *et al*, 2004

extracted groundwater is used for irrigation, especially in the dry season. Arsenic levels in rice in Bangladesh are as high as 1.8 ppm compared to 0.05 ppm in Europe and USA (FAO, 2006).

If the arsenic problem is not dealt with immediately by the GBM region countries (India, Nepal, Bangladesh) existing levels of food security will be severely undermined, poverty will therefore increase and public health will be threatened, as all the countries mentioned above depend on groundwater both for food production and domestic use.

Conclusion

The proceeding discussions clearly indicate that Bangladeshis struggling to overcome the twin problems of reducing poverty and improving food security. The single most important driver for both is water. But Bangladesh has very little control over its water as most of the water comes from catchments located in the upper riparian countries. All the poverty and environmental hotspots are directly impacted by water, either too much or too little. It is therefore important to develop and implement an integrated water resource management plan involving all the common riparian countries to comprehensively address the issue of poverty and food security. The problem of salinity intrusion can also be addressed with such collaborative approach. Climate change will also further aggravate the situation, especially in Bangladesh, and will require joint efforts to face the climate change-related problems.

Increasingly reduced flow in the international rivers during the dry season is having a severe affect on the Sundarbans and its ecosystems (PRDI, 2008). This is a UNESCO-designated World Heritage site, so it is an obligation for the countries in the region to save it from degradation by strategic management of water resources (PRDI, 2008).

Crop productivity for major cereals in Bangladesh is very low. This might be the case in India also. Joint effort must therefore be made to increase crop productivity for positive impact in reducing poverty and increasing food security. Joint effort should also be made to address the problem of arsenic contamination of the food chain. Simultaneously, collaborative research should be initiated to develop salinity-, submergence-, drought- and arsenic-tolerant varieties of different crops.

Priority areas for joint research and action

Based on the above analysis the following recommendations are made to improve water productivity, food security and reduce poverty:

- Meteorological and hydrological data exchange has started in a limited way. This should be further expanded and strengthened;
- The potential water problem in the GBM region can only be solved through an integrated approach to the management of existing water resources. Basin-wide harnessing, development, sharing and management of common water resources must be carried out under a wider context of a sustainable water resources management programme;
- Agricultural technology transfer programs within the region should be strengthened to increase technical efficiency, which in turn will help to increase crop production. Wherever possible, multiple uses of water should be exploited in order to increase water productivity;
- Narrow technological and germplasm bases for drought-, submergence- and saline-tolerant crops limit crop choices. Extensive research should carry out to invent sufficient amount of tolerant varieties;

- There is big gap in yield of crops between research stations and farmers' fields. Extensive research should be carried out to minimise the gap, which would increase the production up to 40%;
- The application of a comprehensive set of water balance and water productivity indicators for spatial and temporal analysis could help in performance evaluation of irrigated crops and devising strategies for improving food production and water productivity;
- A good soil should have at least 2.5% organic matter, but in Bangladesh most of the soils have less than 1.5%, and some soils even less than 1% organic matter. The organic matter content of top soils under high land and medium high land situation has been declining over time. It should be taken under consideration and further research should be carried out to find the way to increase soil organic matter content;
- E-flow of the rivers should be increased to the required level. For this, regional cooperation would be essential among all the riparian countries;
- Regional programmes should be developed to combat flooding and drought, two principal causes for both reduced food security and increased poverty;
- Regional research programme for developing salinity-, drought- and submergence-tolerant crop varieties should be developed to reduce crop damage. BRRI in collaboration with IRRI has already developed rice varieties for salinity-, drought- and submergence-tolerance (BRRI, 2010). But some of them are yet to be released. Other countries in GBM region may also have developed similar varieties. These programmes should be strengthened by collaboration in germplasm exchange, field trials, extension to the farmers and their performance evaluation. Salinity-tolerant variety has been developed for the Aman season, which is essentially the wet season and salinity levels are low. Efforts, therefore, should be made to develop varieties that sustain higher levels of salinity. Regional research should be strengthened to develop such varieties for other crops (BRRI, 2010);
- Arsenic contamination in the shallow aquifers has caused a new and potentially dangerous threat to poisoning the food chain. This is a regional problem involving Bangladesh, India and Nepal. A regional programme should be started immediately to address the issue;
- Until a formal arrangement can be made at the official level, Track-II level consultation (between scientists, civil society groups of the riparian countries) should continue; and
- A commission in line with the Mekong River Commission, which has successfully addressed the problem of trans-boundary rivers, may be established for integrated management of water resources.

Regional framework for water management

Since water is the key to life, preserving this and sustaining the development initiative is now a key concern to the water sector policy makers in Bangladesh. One clear-cut evidence is that the government of Bangladesh is much concerned about maintaining the environmental flow in the major rivers, which is the amount of water needed in a watercourse to maintain healthy, natural ecosystems. Following criteria may be considered for developing water infrastructures and strategies:
- Minimise resource use and ecological impacts throughout the life cycle;
- Preserve ecosystem integrity;
- Unaggravate adverse global phenomena as climate change;
- Deliver economically viable goods and services; and
- Maximise long-run economic growth for the benefit of all.

Strategy should consider to:

- Integrate infrastructure in the overall national sustainable development framework;
- Integrate sustainability concepts into sectoral policies;
- Integrate among sectors (e.g. land-use planning and transport);
- Identify and internalise externalities; integrate them into sectoral policies and at project level; and
- Consider social, economic and environmental attributes (Economic Sustainability, Livelihood, Increase in Farmer Income, Increase in Non-Farmer Income, Change in Water Quantity, Change in Land Quality).

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Review of literature

A number of books, reports and journals have been reviewed extensively. The important ones are cited below:

- Mirza *et al*, 2008 is an anthology that seeks to provide an authentic debate, backed up by science, to the readers regarding the Indian River Linking (IRL) concept. The book assembles scientists belonging to opposing schools of thought from South Asia, Europe, Australia and North America. The anthology provides a scientific basis of understanding the dynamics and implications of large scale water transfer from a network of international and national rivers. It has not tried to draw any general conclusion on the ILR concept; instead, it has provided the likely scenarios.
- Falkenmark *et al*, 2005 focuses on four key areas in which society interacts with water. Besides aquatic ecosystems, this book also focuses on terrestrial ecosystems.
- The environmental effects, on both sides of the border between Bangladesh and India, caused by Ganges water diversion was described by Mirza, 2004. A balanced approach is adopted in reporting the environmental changes of water diversion. Deviating from the usual focus of reporting only adverse effects, positive effects of Ganges water diversion are also included. In addition to a thorough analysis of the environmental effects and implications, this book discussed three important issues: risk analysis, vulnerability and adaptation related to water diversion.
- The existing flood forecasting and warning capacity of Bangladesh could be more effective if real-time data could be acquired from upstream areas within the GBM catchment, where runoff is generated. In order to do so, Bangladesh needs to foster an effective regional cooperation with the other GBM regional countries of India, Nepal and Bhutan, suggest Q.K. Ahmad & Ahsan Uddin Ahmed, 2000.The article examines how GBM regional cooperation could be useful toward managing floods in Bangladesh, in particular, and the region in general.
- Q I Siddique, 2002 focuses on the issues and potential of water resources in the region, highlighting constraints on its development and emphasizing the necessity of regional co-operation between India, Nepal, Bangladesh, Bhutan and possibly China for water resource management through flood mitigation, food production, environment protection and power development in the GBM basin.
- Q K Ahmed *et al*, 2001 indicate one of the most important natural resources of the GBM region is water. So, it is absolutely critical this resource be developed and managed in a rational, efficient and equitable way, so that it can act as the engine for the socio-economic development of the region. A climate of goodwill and mutual trust has started to develop between the concerned countries to uplift millions of poverty-trapped people by signing treaties (between India-Nepal and between India-Bangladesh), arranging consultation workshops and so on.
- Q K Ahmed *et al*, 2001 in the book *Converting Water into Wealth-Regional Cooperation in Harnessing the Eastern Himalayan Rivers*, has made an effort in putting together factual information, relevant data and ideas in order to develop a consensus for promoting optimal, integrated and equitable development in the eastern Himalayan rivers. This study is a collaborative effort and reflects a common understanding, addressing policy makers, technocrats as well as the common people of the region.
- B G Verghese, 2001 is about the impact of a project jointly done by CPR, BUP and IIDS, non- governmental research organizations of India, Bangladesh and Nepal respectively. Against the background of an impasse at the inter-governmental level and an atmosphere of mutual mistrust and suspicion, a serious effort was needed at a non-official level to promote inter-country understanding and improve relationship in general terms as also to explore avenues of settlement of outstanding issues, particularly in the area of water resources. This was the idea behind the project and is popularly known as the Track II effort.
- A M Dewan and K Nizamuddin, 1999 has stated that the reduction in dry season flows and various environmental degradation in the south-west part of Bangladesh have been happening due to the construction of the Farakka Barrage in India. Based on a questionnaire survey in south-western Bangladesh, this paper presents perceptions of local communities regarding the impact of the Farakka Barrage on the region.

- The utilization of water of the GBM river systems is a very sensitive issue. Critical challenges prevail among the countries while implementing mutually beneficial policies and programmes. The book by Ahmad *et al,* 1993 focuses on the study undertaken with a view to identifying and analyzing constraints on fuller utilization of water and how such constraints may be removed within Bangladesh and suggesting areas of regional cooperation toward an equitable sharing of river flows among co-riparians of the GBM river systems.

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