***February 6, 2008***

# Implications of Climate Change on Water Management in Bangladesh


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## 1. Introduction

Bangladesh is a lower riparian country in the basins of the Ganges, the Brahmaputra and the Meghna (Figure1). Being located at the lower ends of the three large rivers and at the head of the Bay of Bengal, impact of climate change has important implications for water management in Bangladesh. Impacts on water resources systems, water related hazards, environment, ecosystems, bio-diversity, socio-economic activities and livelihoods due to changes in water regimes are of great concern. Climate change impacts have been seen as a major knowledge gap in the National Water Management Plan (WARPO, 2001) of Bangladesh. This paper briefly discusses some of the implications of climate change on water management in Bangladesh.

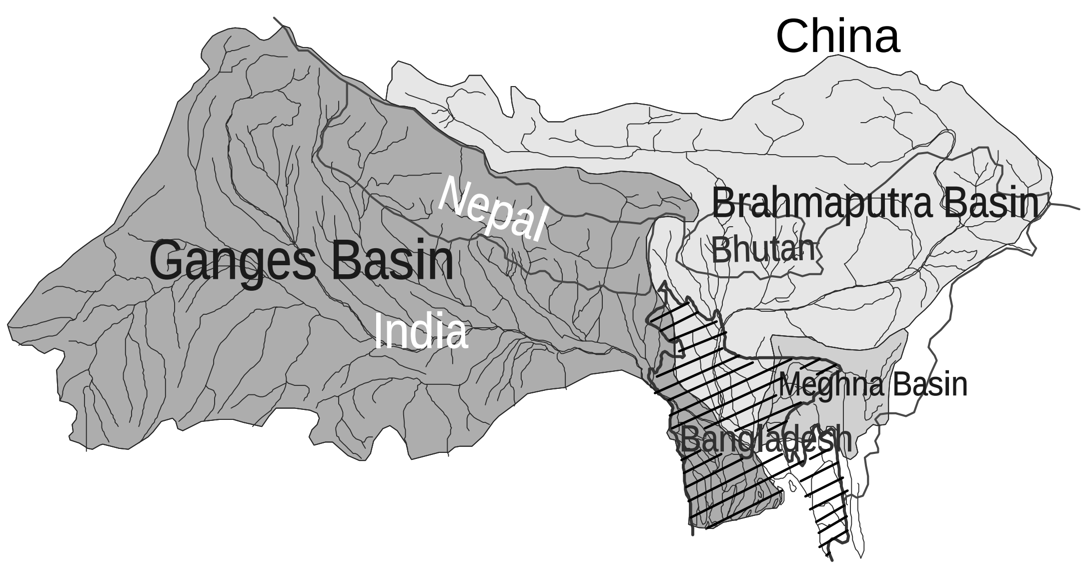


**Figure 1** Ganges, Brahmaputra and Meghna basins and location of Bangladesh

## 2. Sources of Surface Water in Bangladesh

Major portion of Bangladesh is formed by deltas of three large rivers the Ganges, the Brahmaputra and the Meghna (GBM). The three large rivers meet inside Bangladesh and the combined out-fall discharges to the Bay of Bengal (Figure 2). Approximately 7% of GBM basins of total area of 1.74 million sq.km. lies in Bangladesh. The extensive floodplains of the three large rivers and their numerous tributaries and distributaries is the main physiographic feature of the country. Annual volume of runoff to the sea is equivalent to about 12 meters of depth over Bangladesh's area under GBM basins. Because of snowmelt in the Himalayas, the Brahmaputra starts rising ahead of monsoon in early April. River flood is an annual phenomena in Bangladesh. Flooding is caused mainly by spill from Brahmaputra and Ganges rivers and their tributaries and distributaries during July to September. Flash floods from the hills occur during the pre-monsoon months of April and May in the Meghna basin of north-east region and in the south-eastern and eastern hills regions.

Water regime in Bangladesh is dominantly influenced by the runoff generated in the catchments of GBM rivers. About 80% of runoff that flows over Bangladesh, is from outside the country while 20% is contributed by local rainfall. Climate change would cause modification in the distribution of temperature, precipitation and evaporation over the basins of GBM rivers, and consequent changes in the hydrologic cycles of the basins would bring changes in water regimes in Bangladesh.

## 3. Prediction of Future Climate

Results from a collaborative research project entitled 'Impact of CLimate And Sea level change in part of the Indian sub-Continent (CLASIC)' are briefly discussed here to give an indication of possible changes in future climate. The climate change impact component of the project has been carried out by Centre for Ecology & Hydrology (CEH), UK, Hadley Centre, Meteorological Office, UK, Center for Environmental & Geographic Information Services (CEGIS), Dhaka and Institute of Water & Flood Management (IWFM), BUET, Dhaka. The project has been funded by DFID, UK, and the CEH is the lead agency. Climate models were run by Hadley Centre. Model runs were made for baseline period of 1979-1999 and for two future periods of 2015-2035 and 2040-2060. Details of the project are in Farquharson et al. (2007).

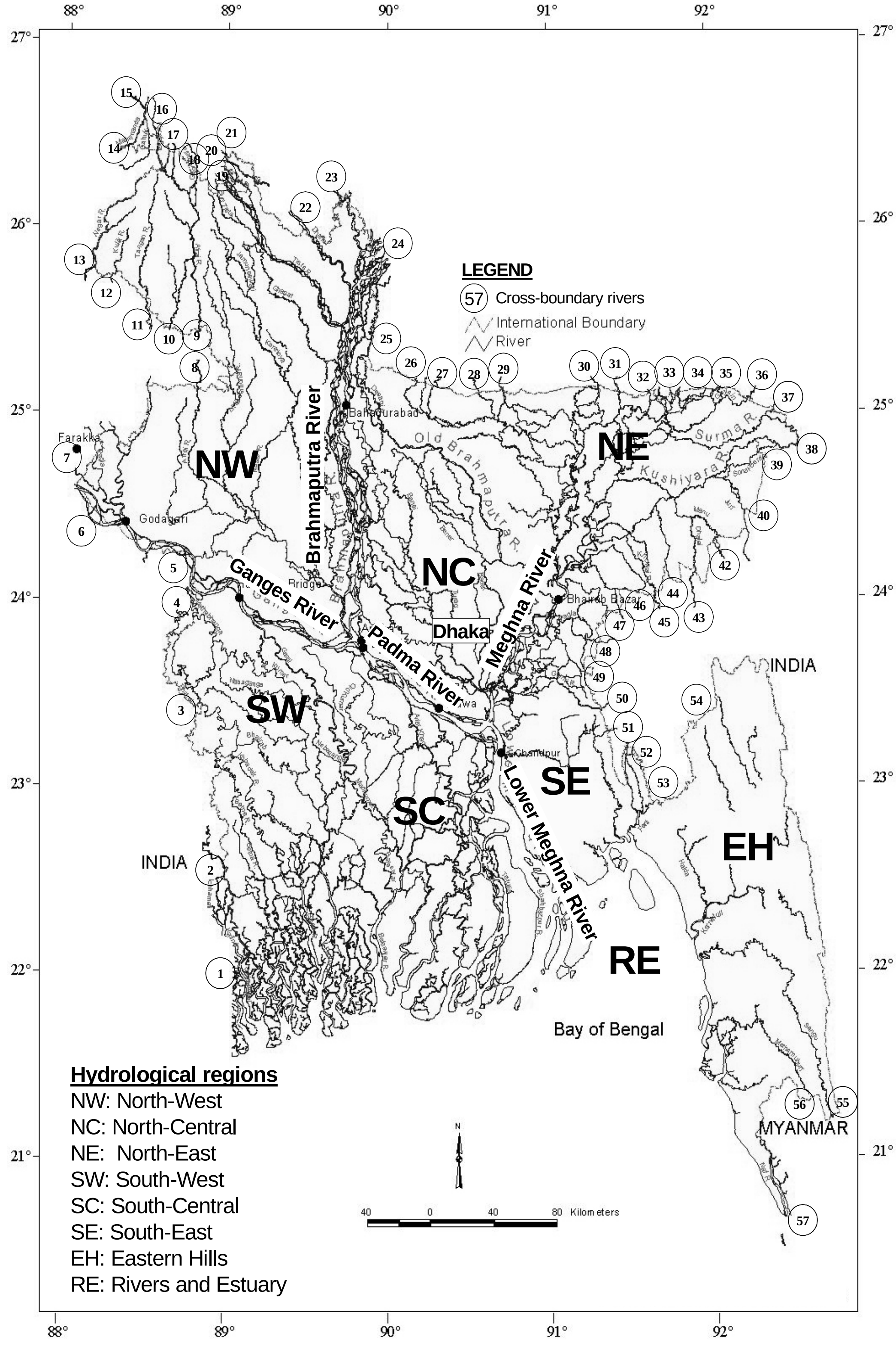


**Figure 2** River system and hydrologic regions of Bangladesh

It has been long established that there is quite large uncertainty in climate model results. There can be large variations as well as conflicting results among the models. Uncertainty is greater in the case of global climate models (GCMs). As an attempt to overcome the issue of uncertainty, four GCMs available for A2 and B2 emission scenarios have been used to predict future climate. Two regional climate models (RCMs) also have been used. The scenarios are based on Intergovernmental Panel on Climate Change (IPCC) website. The aim was to analyse a range of results from a variety of climate models to gauge the possible range of future situations.

Average monthly values of precipitation and potential evaporation in Bangladesh for baseline and future periods as derived from results of RCMs (HadRM2 & PRECIS-A2) from the Hadley Centre are discussed here. HadRM2 model uses a different emission scenario that considers 1%/year increase in $CO_2$ from 1990 onwards. Results in Figure 3(a) mostly show increase in precipitation during May to November while decrease during December, January and April. Results in Figure 3(b) mostly show increase in potential evaporation during July to March while decrease during April to June. Results of the GCM (HadCM3-A2) for precipitation and potential evaporation are opposite to that obtained from RCMs. Changes in precipitation and evaporation have important implications for surface water and groundwater regimes as discussed below.

## 4. Possible Climate Change Impacts on Surface Water and Groundwater

The main objective of CLASIC project, discussed in Sec. 3, is to investigate possible climate change impacts on surface runoff characteristics in Bangladesh. Using predicted climate as input, a hydrological model called 'Global Water AVailability Assessment (GWAVA )' has been used to simulate surface water runoff. The GWAVA software was developed by the CEH and the British Geological Survey. The surface water runoff process of Ganges-Brahmaputra-Meghna Basins has been simulated by a coarse scale representation at $0.5^0$x$0.5^0$ resolution. Bangladesh is represented by a fine scale resolution of $0.1^0$x$0.1^0$ (approx. 11km x 11km). The coarse grid model provided boundary conditions for the fine grid model. The hydrological model was run by CEH and IWFM. A tool developed by CEGIS for the generation of flood map was used to predict future flooded area. Although the CLASIC project was competed in 2007, the impact study using the fine grid hydrological model has been continued to develop further insight to the impact on surface runoff characteristics in Bangladesh. Some of the results based on climatic input from RCMs of the Hadley Centre are briefly discussed in the following sections.

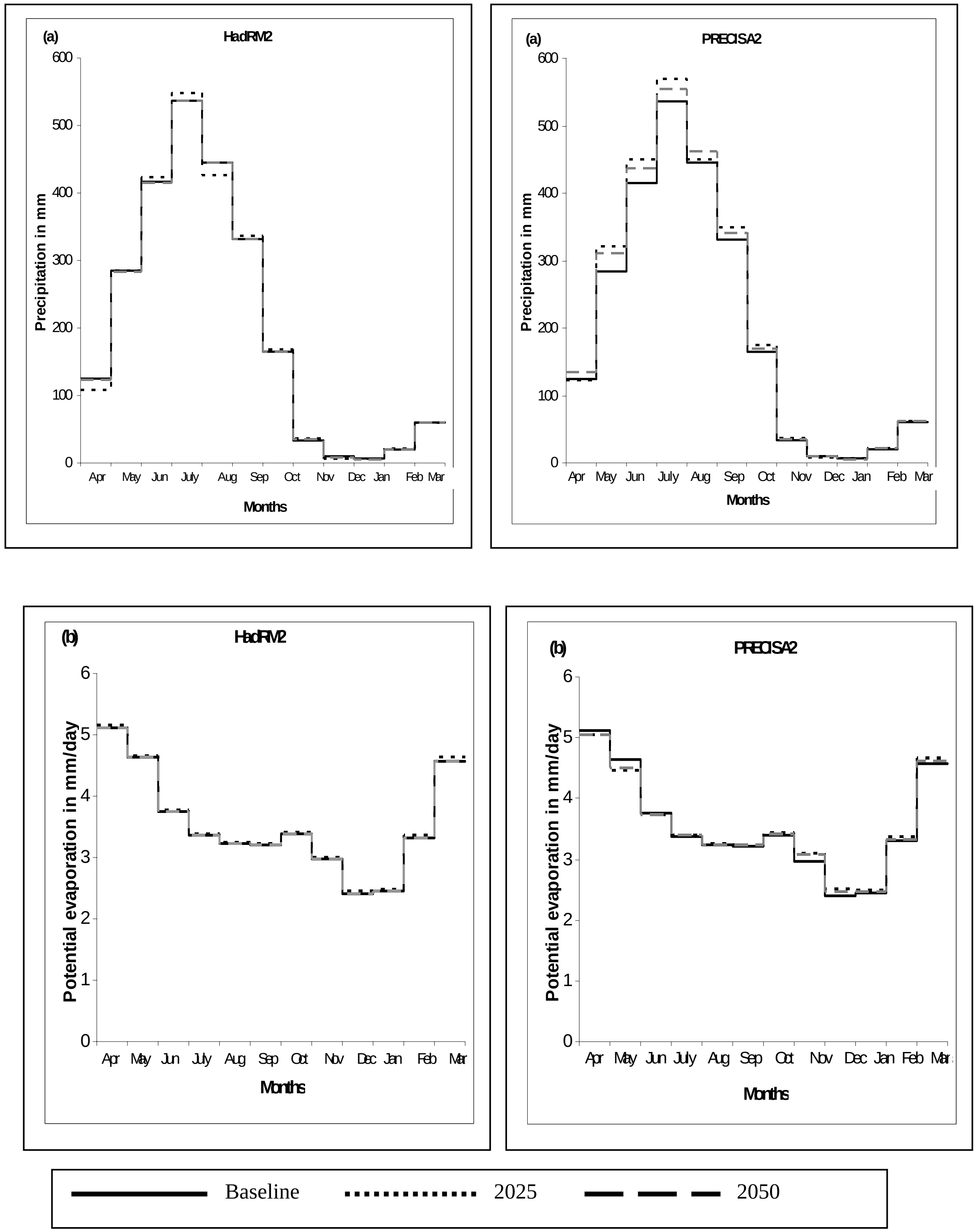


**Figure 3** Comparison of average monthly precipitation and potential evaporation over Bangladesh for the periods 2015-2035 (2025) and 2040-2060 (2050) with baseline values based on results from two RCMs.

Water regime in Bangladesh is mainly dependent on flows of the Ganges, the Brahmaputra and the Meghna that is fed by the Barak. Contribution of the Brahmaputra, the Ganges and the Meghna to the annual flow in Bangladesh is approximately in the ratio of 9:5:2. Results based on climatic input from PRECIS-A2 show increase in the annual flow volumes for the Brahmaputra and the Barak while that based on HadRM2 shows decrease. Results based on both models show decrease in the annual flow volume for the Ganges.

The changes in wet season flow volumes are almost similar to that in the annual flow volumes. This is because wet season flow forms major portion of the annual flow. Flood regime during wet season is dominated by the Brahmaputra. Hydrographs based on predicted river flow indicate early start of the rising limb as well as early start of the recession limb (Figure 4). The figures indicate possibility of lager magnitudes of the annual peak flood discharges compared to the baseline. There is possibility of early floods in the Brahmaputra.  There is also possibility of larger early flash floods in the Meghna that is fed by Barak. Prediction by flood mapping model indicate increase in flooded area compared to the baseline.

Results based on both RCMs indicate that the dry season flow volume of the Ganges would decrease and that of the Brahmaputra would increase. Results from hydrological model of GBM basins show that with the increases in water demand, there is a general increase in the water deficit, especially along the Ganges in India (Fung et al., 2006). Decrease in the dry season low of the Ganges is a major concern since the flow is already reduced by diversion at Farakka Barrage in India. For the Barak, results based on HadRM2 indicate decrease while that based on PRECIS-A2 indicate increase. Water availability analysis indicates that the areas of Bangladesh that are already under water stress would be more stressed in future. North-west and south-west regions would be the worst sufferer among the areas that are likely to face increased water deficit.

The Yalong Zangbo (Brahmaputra River in Tibet) is mainly fed by glacier melt rather than precipitation and therefore the large decrease in flow at Yangcun and the subsequent changes in flow at Bahadurabad can possibly be attributed to the large decreasing glacier areas in the region (Farquharson et al., 2007).

The major source of groundwater recharge is the deep percolation from the infiltrated rainwater during monsoon. The increase in open water and soil/plant evaporation due to climate change would cause reduction in soil moisture. Therefore larger amount of

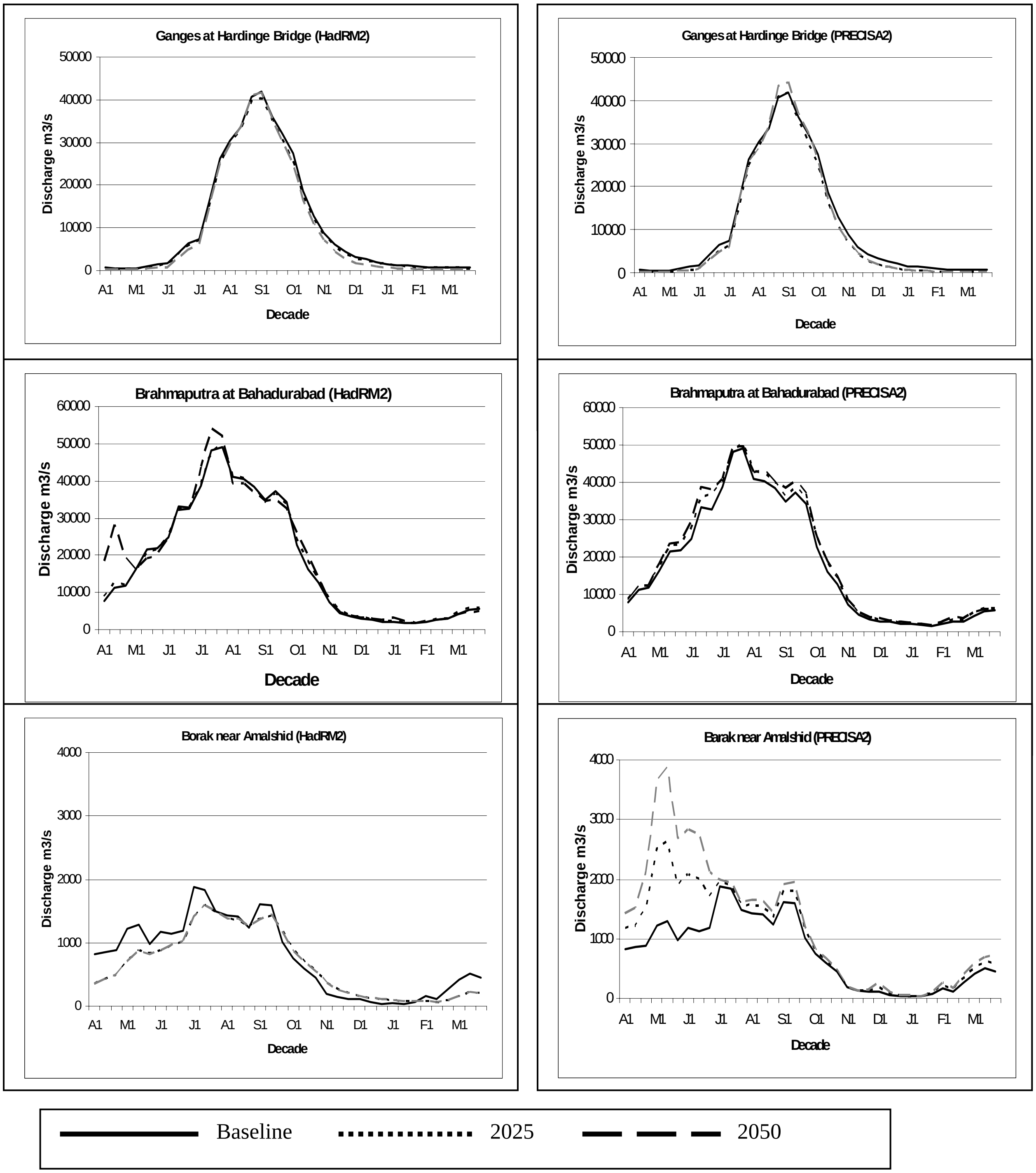


**Figure 4** Comparison of hydrographs of GBM rivers at locations in Bangladesh for the periods 2015-2035 (2025) and 2040-2060 (2050) with baseline based on climatic input from two RCMs.

infiltrated water would be captured by soil storage. This would cause reduction of the deep percolation since the infiltration capacity has an upper limit that depends on soil type. As a result groundwater recharge is likely to be reduced. If rainfall decreases in future, more reduction of groundwater would take place. Groundwater storage is the source of base flow in the rivers during dry season. Thus reduction of groundwater storage is likely to cause decrease in the dry season flow.

## 5. Implications on Water Management

***Capacity exceedance risk for flood and drainage management infrastructures:*** Flood is an annual phenomenon in Bangladesh, and most of the investment in water management is on flood control and drainage projects. Main cause of flooding in Bangladesh is the spill of river flow during wet season. Flood control projects involve construction of embankment along the riverbank in order to prevent the spill of flood water from the river. Drainage of surface runoff generated by local rainfall is a complex process since water level in the river usually remains high in the river during monsoon. The local runoff is detained in low lying areas and wetlands. There is possibility of increase in the local rainfall as well in the river flow from upstream during wet season due to climate change as discussed earlier. This will pose a challenge for flood and water management in Bangladesh. The capacities of existing drainage infrastructures may not be adequate to accommodate the increased local runoff, and consequently risk of local rainfall flooding would increase. This will be particularly crucial for urban areas. The increase in the river flood peak due to increase in the upstream flow can cause over topping of existing flood control embankment. Consequently frequency of embankment failure flood can increase in the future if required steps for adaptation are not taken. There is also possibility of increased riverbank erosion because of the increase in flood flow.

***Risk of water shortage for domestic and industrial water supplies:*** The rural domestic water supply is mainly based on hand tubewells that lift groundwater from shallow aquifer. Domestic and industrial water supply systems in urban areas utilize both river water and groundwater. Climate change can cause decrease in the river flow during dry season and in the groundwater storage as discussed earlier. As a result domestic and industrial water supply systems are likely to face water shortage. Increase in water demand due to population growth would aggravate the situation further. This is a crucial issue for water management since it will adversely affect the public health security.

***Risk of water stress in irrigation projects due to increase in evaporative demand:*** Predicted future values of climatic variables in Figure 3 indicate possibility of increase in potential evaporation during July to March. Hence higher crop evaporative demand would cause increase in irrigation water requirement for Aman and Boro cultivation. On the other hand the decrease in the water availability due to possible decrease in the dry season flow of the river would add make the situation more difficult. The increase in crop water requirement and decrease in water availability would cause water stress in irrigation projects which is likely to be a major concern for the management of agricultural water supply. Adverse impact on irrigation projects would cause negative effects on socio-economy since agriculture sector is the largest employer in rural areas. Another concern is the impact on food production.

***Risk of fresh water scarcity in irrigation projects due to saline water intrusion:*** The fresh water inflow to the combined outfall of GBM rivers during dry season performs a very important function by controlling saltwater intrusion from the Bay of Bengal. Minimum in-stream flow required to control saline water intrusion in the Lower Meghna which is the combined outfall of GBM rivers, has been determined by Chowdhury and Haque (1990). Corresponding in-stream flow requirement at Bahadurabad on the Brahmaputra has been estimated by Chowdhury and Hossain (2003). Decrease in fresh water flow below the minimum in-stream requirement would cause harmful intrusion of saline water. There are several irrigation projects in south-central (SC) and south-west (SW) regions that are dependent on the flows of the distributaries of the Ganges, the Padma and the Lower Meghna. Decrease in the dry season flow of GBM rivers would cause increase in the saline water intrusion in the distributaries in SC and SW regions. The irrigation projects in these regions would be subject to the risk of fresh water scarcity due to increase in the saline water intrusion during dry season. Decrease in the Ganges flow due to diversion at Farakka during dry season by India has already created severe water shortage and saline water intrusion in the SW region. The impacts on irrigation projects would adversely affect the socio-economy in these regions where poor livelihood groups form major portion of the population.

***Risk of wetland ecosystems degradation due to change in wet season flow regime:*** A characteristic landscape feature in Bangladesh is the presence of many wetlands in the extensive floodplains. These wetlands are rich in ecological resources and bio-diversity. These wetlands are recharged mainly through khals and rivers during wet season. The life cycles of wetland species of fauna like fish, snails, frogs etc. and wetland plants are intimately related to the water flow process associated with the hydraulic linkage between wetlands and rivers/khals. The likely changes in wet season flow of the rivers due to climate change would bring changes in the process of wetland recharge. Consequently the aquatic habitats in wetlands would be adversely affected. The Sundarban ecosystem also would be adversely affected due to increase in the saline water intrusion. The ecosystem degradation would cause adverse impacts on socio-economy since a large portion of poor livelihoods in rural areas is dependent on ecological resources.

***Increase in the risk of cyclonic storm surge flood due to sea level rise:*** Possible sea level rise due to climate change has long-term implications for coastal zone management in Bangladesh. Some implications of sea level rise are loss of land, impediment of the drainage of flood flow of the GBM rivers, increase in frequency and intensity of cyclonic storm surge floods from the Bay of Bengal. Results from CLASIC project (Farquharson et al., 2007) indicate that the largest changes in extreme water levels of cyclonic storm surges is due to rise in mean sea level. On the west of the Bay an extreme water level that has a return period of 50 years under the present climate is forecast to have a return period of about 5 years under the changed climates due to changes in storminess and the increase in relative mean sea level. These results indicate possibility of very large increase in storm surge flood depth in the coastal areas. An implication is that existing shelters may become inadequate to give protection against future storm surge floods. Shelters would be needed in additional areas because of the upland progression of the minimum depth that necessitates shelter construction. Shelter planning should keep the provision so that adaptation to these changes in the storm surge risk is possible.

***Risk of disruption of inland water transport:*** Bangladesh is criss-crossed by more than 200 rivers. The dense network of rivers and khals provides a cheap means of waterway transport. Possibility of decrease in the river flow during dry season due to climate change can be a cause of disruption of inland waterway. Increase in the agricultural water demand due to climate change as discussed earlier, would lead to larger volume of water withdrawal from rivers in future for irrigation. Consequent decrease in river flow would be a hindrance for water transport. Likely decrease of the Ganges flow is a major concern in this respect since the flow of the Ganges has already been reduced by water diversion at Farakka Barrage in India during dry season. Due to decrease in water depth in the Ganges because of water diversion at Farakka, the round the year navigation route along the Ganges from Aricha to Gudagari had to be converted to seasonal route since 1985.

## 6. Concluding Remarks

Possible changes in wet season and dry season flow regimes due to climate change may have serious implications on water management in the deltaic setting of Bangladesh. A major concern for water management is the possible increase in water related hazards and decrease in water availability. These impacts can have enormous consequences on socio-economy, environment and ecosystems. Being a lower riparian country, water regime in Bangladesh is dependent on the flows of the Ganges, the Brahmaputra and the Meghna from upstream. Basin wide planning of water management is essential to address the issues related to the possible impacts of climate change over the three river basins**.**

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