Climate change-induced challenges to sustainable development in Bangladesh

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Abstract. Bangladesh is one of the most vulnerable countries to the impacts of climate change due to its low-lying deltaic landforms and close proximity to the Bay of Bengal. Therefore, climate change and its consequences are critical hindrance to the vision of sustained socio-economic growth of the country. With the evolving climate change, Bangladesh has been frequently facing extreme climatic events, such as erratic rainfall, flooding, drought, sea-level rise, cyclones, and salinity intrusion. Climate change will worsen many of the current problems and natural hazards that the country faces. The mean temperature is projected to rise by 1.0 to 1.4°C during 2046–2065 and 1.0 to 3.7°C during 2081–2100. Rainfall is likely to change with more erratic pattern in the future. The western parts and drought-prone areas of the country will be at greater risk from droughts. The extent of flood intensity from cyclonic storm surges is likely to increase. The predicted sea-level rise in the coastal zone is 0.2–1.0 m in 2100, with a current trend of 6–20 mm year⁻¹. The rising sea level, along with cyclonic storm surges, will increase the intensity and extent of coastal flooding, accelerate salinity intrusion, and hinder freshwater availability. The areas under 1 ppt and 5 ppt salinity in base (2005) condition will increase to 17.5 ppt and 24 ppt salinity, respectively by 2050 under extreme climate scenario. Under moderate climate scenario, crop production will decline by 27% for Aus rice and 61% for wheat. The yield of Boro rice may reduce by 55–62% under extreme climate scenario. The reduced crop yield will negatively influence food security, and lives and livelihoods of millions of people in the country. Thus, climate change will become a major threat to Bangladesh’s aspirations to ensure food security, poverty alleviation and sustainable development.

1. Introduction
Bangladesh largely comprises low and flat land, except for the hilly regions in the north-east and south-east, and highlands in the north and north-west. About 70% of the country is one meter or less above mean sea level; floodplains occupy almost 80% of the country [1]. Under current climate conditions, the country is exposed to a multitude of natural hazards such as floods, cyclones, heat-waves, river-bank erosion, drought, storm surges and salinity intrusion. Heavy monsoon rain over the highlands and tropical storms in the coastal region trigger coastal floods. Sudden rainstorms in April–May create immediate run-off, causing flash floods in the north-east (Hoar region). Almost every year, cyclones hit the coastal region of the country and, on average, a severe cyclone strikes the country once in 3 years. An average flood causes 20–25% of the country to be flooded. Rising sea level increases salinity intrusion and, consequently, impedes availability of freshwater. With a combination of flood plain and drought-prone areas, the country is faced with an abundance of water on one hand, and agricultural droughts on the other [2]. Agricultural drought refers to circumstances when soil moisture is insufficient.
and results in the lack of crop growth and production. It primarily concerns itself with short-term drought situations.

The temperature will increase in Bangladesh in the future following the trend of global warming. Two future situations – Business As Usual (BAU) scenario and Extreme (EXT) scenario – are considered for climate change in Bangladesh [3]. The BAU scenario (Representative Concentration Pathways RCP4.5) considers moderate climate change scenario, which assumes that the global and national efforts to reduce greenhouse gas (GHG) emissions are maintained. The EXT scenario (RCP8.5), on the other hand, considers the extreme climate change scenario with no global and national efforts to reduce GHG emissions and assumes continued pursuit of fossil fuel-based economic development.

Agriculture (including horticulture, forestry, livestock and fisheries) is the most climate-sensitive sector. Even under the moderate climate change scenario, Bangladesh, and particularly its agriculture, is considered to face severe challenges of falling crop yields, loss of agricultural land, degrading quality of aquifer, loss of biodiversity, and extreme weather events. The combined effects of these challenges could seriously threaten livelihoods of people who are dependent on agriculture and related occupations. Every year, climate-induced natural disasters cause either partial or total loss of crops in some areas of Bangladesh. Flood being a recurrent phenomenon is one of the major causes of crop damage almost every year. The devastating floods of 1987, 1988 and 1998 inundated more than 60% of the country [4]. The 1988 flood inundated 61% of the country with estimated damage of USD$ 1.2 billion and caused more than 45 million people homeless [5]. About 5.46 million hectares of land have been estimated as drought-affected area [6], and 1.06 million hectares are salinity-affected land [7] in Bangladesh; the salinity-affected area is continuously increasing with time.

The coastal zone of Bangladesh is highly susceptible to natural disasters like cyclones, storm surges, and floods due to its geo-morphological and hydrological realities. Due to climate change, these disastrous events are becoming extreme with higher intensity and frequency. The Global Climate Risk Index 2010 [8], covering the period 1990–2008, estimated that, on an average, 8,241 people had died each year in Bangladesh while the cost of damage was around USD$ 2.2 billion per year and loss of Gross Domestic Product (GDP) was 1.81% during that period. In 2007, the devastating cyclone Sidr caused thousands of deaths and damages to agriculture; the estimated cost of damage was around USD 3 billion [9].

Bangladesh is projected to face 2.0% loss of annual GDP by 2050 and more than 9% of GDP by 2100 under the BAU climate scenario [4]. Bangladesh would experience a net increase in poverty of approximately 15% by 2030 [10] due to the impacts of climate change. Therefore, it is necessary to adapt to the impacts of climate change to improve the resilience of food production systems in order to feed the growing population of the country. Strategic approaches to address climate change impacts, in terms of adaptation and mitigation, are to be articulated as key ingredients of development planning.

2. Climate Change in Bangladesh

The fifth Assessment Report (AR5) of IPCC states that Bangladesh is among the countries that will be at most risk from extreme events [10]. The Global Climate Risk Index 2017 [11] analyzed to what extent countries have been affected by the impacts of weather-related loss events (storms, floods, heat-waves, etc.). It ranked Bangladesh in 7th position among the most at-risk countries of the world from extreme events due to climate change. IPCC [10] projected global warming for selected time slices for different Representative Concentration Pathways, RCPs. In spite of some variations in the projected future global climate change, there is a consensus that global warming will increase and so will be the case for Bangladesh in the 21st century. By the end of this century, the maximum temperature is projected to increase by 2.0–2.5°C for the RCP 4.5 (BAU) scenario, and by up to 4°C under the RCP 8.5 (EXT) scenario [3]. The region-wise seasonal changes in temperature and rainfall in Bangladesh during 2030 and 2050 under the BAU scenario are presented in table 1 and table 2, respectively. The temperature might rise in the country by 1.4–1.9°C for the BAU scenario and 2°C for EXT scenario by 2050. Further rise in temperature is also expected in the latter half of the current century. There is an indication that the pre-monsoon and monsoon rainfall will increase under the BAU scenario (table 1) in most regions
Rainfall patterns may become more variable and erratic [3], especially during the pre-monsoon and monsoon seasons that will receive more rainfall.

**Table 1.** Projected seasonal and annual change in maximum and minimum surface temperature (°C) for Business As Usual (BAU) scenario in seven hydrological regions of Bangladesh (figure 1) (DJJ: December–January–February, MAM: March–April–May, JJAS: June–July–August–September, ON: October–November, NW: North–West, NC: North–Center, NE: North–East, SW: South–West, SC: South–Center, SE: South–East, EH: Eastern Hills). (Source: Stocker, 2014[12]).

| Region | Seasonal change for 2030 | Annual change | Seasonal change for 2050 | Annual change |
|--------|-------------------------|---------------|-------------------------|---------------|
|        | DJF| MAM | JJAS | ON | DJF| MAM | JJAS | ON |
| maximum temperature | | | | | | | | |
| NW    | 1.5 | −0.1 | 1.3 | 1.1 | 1.0 | 2.3 | 0.6 | 1.9 | 1.9 | 1.7 |
| NC    | 1.4 | −0.3 | 1.3 | 1.0 | 0.9 | 2.3 | 0.5 | 1.9 | 1.6 | 1.6 |
| NE    | 1.4 | 0.0 | 1.3 | 1.1 | 1.0 | 2.2 | 0.5 | 1.9 | 1.6 | 1.6 |
| SW    | 1.2 | 0.0 | 1.0 | 0.8 | 0.8 | 2.2 | 0.9 | 1.6 | 1.2 | 1.5 |
| SC    | 1.1 | 0.4 | 1.0 | 0.8 | 0.8 | 2.0 | 1.1 | 1.5 | 1.2 | 1.5 |
| SE    | 1.2 | −0.1 | 1.2 | 0.9 | 0.8 | 2.1 | 0.6 | 1.7 | 1.3 | 1.4 |
| EH    | 1.0 | 0.4 | 1.0 | 0.8 | 0.8 | 1.6 | 0.9 | 1.5 | 1.2 | 1.4 |
| minimum temperature | | | | | | | | | |
| NW    | 1.4 | 0.6 | 1.2 | 1.4 | 1.1 | 2.3 | 1.3 | 1.7 | 2.3 | 1.9 |
| NC    | 1.5 | 0.6 | 1.2 | 1.4 | 1.1 | 2.4 | 1.2 | 1.7 | 2.3 | 1.8 |
| NE    | 1.6 | 0.8 | 1.2 | 1.6 | 1.3 | 2.4 | 1.2 | 1.8 | 2.4 | 1.9 |
| SW    | 1.3 | 0.6 | 1.1 | 1.1 | 1.0 | 2.4 | 1.3 | 1.6 | 1.9 | 1.8 |
| SC    | 1.3 | 0.7 | 1.0 | 1.0 | 1.0 | 2.3 | 1.3 | 1.5 | 1.7 | 1.7 |
| SE    | 1.4 | 0.6 | 1.1 | 1.3 | 1.1 | 2.4 | 1.2 | 1.6 | 2.0 | 1.8 |
| EH    | 1.3 | 0.9 | 1.1 | 1.2 | 1.1 | 2.2 | 1.5 | 1.7 | 1.9 | 1.8 |

**Table 2.** Projected seasonal and annual change in rainfall (%) for Business As Usual (BAU) scenario in seven hydrological regions of Bangladesh (figure 1) (DJJ: December–January–February, MAM: March–April–May, JJAS: June–July–August–September, ON: October–November, NW: North–West, NC: North–Center, NE: North–East, SW: South–West, SC: South–Center, SE: South–East, EH: Eastern Hills). (Source: Stocker, 2014[12]).

| Region | Seasonal change for 2030 | Annual change | Seasonal change for 2050 | Annual change |
|--------|-------------------------|---------------|-------------------------|---------------|
|        | DJF| MAM | DJF | ON | DJF| MAM | JJAS | ON |
| NW    | 134.0 | 19.9 | −6.1 | 116.1 | −0.1 | 119.3 | −18.6 | 5.6 | 28.8 | 4.5 |
| NC    | 107.6 | 34.1 | 14.8 | 47.7 | 19.0 | 31.2 | −5.1 | 20.6 | 12.6 | 16.9 |
| NE    | 32.0 | 7.1 | 15.0 | 8.1 | 13.1 | 12.1 | −0.9 | 17.9 | 9.8 | 13.2 |
| SW    | 68.8 | 11.9 | 1.4 | 76.4 | 6.0 | 58.2 | −20.3 | 0.7 | −7.8 | −1.5 |
| SC    | −6.7 | 15.7 | 3.4 | 45.4 | 6.3 | 0.2 | −1.5 | −2.1 | −11.4 | −2.5 |
| SE    | −5.1 | 26.6 | 10.9 | 6.6 | 12.3 | 7.2 | 9.6 | 5.0 | 0.6 | 5.4 |
| EH    | −32.9 | −20.1 | 1.8 | −35.4 | −2.8 | 45.0 | 2.2 | −1.3 | −33.7 | −1.6 |
3. Bangladesh’s Challenges
Bangladesh faces several climate change-related challenges in its socio-economic developments. The major challenges are (i) floods, (ii) drought, (iii) river-bank erosion, (iv) sea-level rise and salinity intrusion, and (v) cyclones and storm surges. These challenges appear mostly due to the country’s geomorphological and hydrological settings. The country has a unique hydro-geologic setting and deltaic floodplains, which are formed by the deposition of the Ganges (Padma), Brahmaputra (Jamuna) and Meghna Rivers. These rivers and their distributaries control the hydrological and fluvio-morphological behaviours of the country. Climate change exerts direct impacts on challenging events. Based on natural hazards and challenges, Bangladesh has been divided into six hotspot regions: Coastal Zone Hotspot, Barind and Drought-Prone Areas Hotspot, Haor and Flash Flood Areas Hotspot, River Systems and Estuaries Hotspot, Chittagong Hill Tracts Hotspot, and Urban Areas Hotspot (figure 2). Each region is exposed to a different set of climate hazards, and hence differently vulnerable to climate variability and change.
3.1. Floods

Bangladesh mostly consists of huge flood plain and delta, of which around 70% of the total area is less than 1 m above mean sea level and 10% of the land area is made up of lakes and rivers. The country experiences heavy monsoon rains along with frequent tropical storms in its southern coastal zone that cause frequent occurrence of floods almost every year. On average, an estimated 20–25% of the country becomes inundated every year due to spilling of the rivers and drainage congestion. Almost 55–60% of the country is inundated during extreme flood events. As a consequence of climate change, the magnitude and frequency of megafloods are increasing [15]. Projections, based on the extreme scenario, suggest that the extent of flood will increase for all areas of the country by 2050. Due to sea-level rise, the extent flooding might increase up to 6% and 8% in the central part of the coastal zone from the base period of 2005 following extreme climate scenario by 2050 and 2100, respectively. Flood causes the most difficult challenge in the Haor and Flash Flood Areas Hotspot (figure 2). Haors are bowl-shaped depressions or natural reservoirs of freshwater wetlands in the North-Eastern region of Bangladesh. They are flooded to a depth of as much as 4–6 m during the rainy season. In most cases during monsoon, two or more Haors become linked and form large water bodies. During the dry season, most of the water in the Haors drains out. The main climate change impact in the Haor and Flash Flood Areas Hotspot is the increase of flash flood risk in the pre-monsoon period. The Haor region remains inundated for several months including some pre-monsoon period, threatening cultivation of crops; the only season in the year for crop cultivation in the region. Often land reclamation by filling up natural wetlands and water bodies reduces water absorption, storage and flood water-holding basins by further increasing the flood risk. The impacts of some recent floods in the country are provided in table 3.
3.2. Drought

Agricultural droughts, which are characterized by severe soil-moisture stress in the agricultural fields compared to the amount required for satisfactory crop growth, occur in some regions of Bangladesh. The mean annual rainfall in the drought-prone north-west region is 1250 to 1750 mm against a country-average annual rainfall of 2300 mm [17]. This rainfall occurs mainly in 4 to 5 wet months (June–October) of the year. The impact of climate change on rainfall patterns, especially during the dry season, is highly uncertain [3]. Drought occurs from January to May due to the cumulative effect of dry days, higher temperatures from March to May and low soil-moisture availability. But, drought during June/July to October occurs due to sub-humid and dry conditions in the highland and medium highland areas of the country. The drought situation becomes severe from April to May due to the cumulative effect of low soil-moisture content, increasing number of dry days and occurrence of extreme summer temperature (often >40°C); the period of dry days is 32 to 48 days. Under the current climate conditions, the average number of days where maximum temperature exceeds 40°C is 20 to 25 days. The mid-century (2050) projections indicate an increase in extreme heat day by 2.5 to 3.5 days, while the end-century (2085) projections indicate an increase of 3.5 to 5.0 extreme heat days for moderate (RCP 4.5) and extreme (RCP 8.5) emission scenarios, respectively [14]. Some projections indicate an increase in the longest period of consecutive dry day by 3.15 days. Under the current climate conditions, the largest period of consecutive dry days is up to 60 days. Under the RCP 8.5 (EXT) scenario, the largest period of consecutive dry day may increase by 10 to 15 days by 2080 [14]. In the past, droughts have affected 47% area of the country and about 53% of the population [4][3]. It is estimated that under the BAU scenario, production will decline by 27% for Aus rice and 61% for wheat. Under the EXT scenario (with 60% moisture stress), the yield of Boro rice may reduce by 55 to 62% [18]. EXT scenario will likely to limit surface irrigation potential in the drought-prone areas and challenge the food self-sufficiency of the country.

The geographical distribution of drought-prone areas (figure 3) has categorized the Barind and drought-prone areas as a Hotspot region (figure 2). The greater part of the Barind Tract is almost plain and is crisscrossed by only a few small rivers. This tract is considered an ecologically fragile ecosystem with very low vegetation cover. The region is characterized by the tendency of high extraction of groundwater and some diversion of river water for irrigation purpose. The reduction of the Ganges water due to upstream withdrawal in India during the dry period and inadequate surface water is further creating problems in this region. There will be a longer dry season and a shorter wet season, but the river discharge will increase only in the wet season. Declining groundwater table due to high extraction will

### Table 3. Impacts of some recent exceptional floods in Bangladesh (Sources: Islam and Mechler, 2007; BWDB, 2007[16]).

| Impacts of floods                      | Year 1974 | Year 1987 | Year 1988 | Year 1998 | Year 2004 | Year 2007 |
|---------------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|
| Area affected (thousand km²)           | 53        | 57        | 90        | 100       | 56        | 62        |
| % total land area inundated            | 37        | 40        | 63        | 69        | 39        | 42        |
| Affected people (million)              | 30        | 30        | 47        | 31        | 33        | 14        |
| Fatalities (no.)                       | 28,700    | 1,657     | 2,379     | 918       | 285       | 1,110     |
| Houses damaged (thousands)             | na        | 989       | 2,880     | 2,647     | 895       | 1,000     |
| Roads damaged (km)                     | na        | na        | 13,000    | 15,927    | 27,970    | 31,523    |
| Crops damaged (Mha)                    | na        | na        | 2.12      | 1.7       | 1.3       | 2.1       |
| Asset loss (million US$)               | 936       | 1,167     | 1,424     | 2,128     | 1,860     | 1,100     |
| GDP (million US$)                      | 12,459    | 23,969    | 26,034    | 44,092    | 55,900    | 68,400    |
| Asset loss (% of GDP)                  | 7.5       | 4.9       | 5.5       | 4.8       | 3.3       | 1.6       |
| Return period (years)                  | 9         | 13        | 55        | 90        | 12        | 14        |
intensify water scarcity because of climate change, and lead to insufficient supply of freshwater in dry periods [19] for the growing population in urban areas. This will create severe problems in the Urban Areas Hotspot (figure 2).

Figure 3. Drought-prone areas of Bangladesh (Source: Hussain, 2017[20]).

3.3. River-bank Erosion
The major rivers – Brahmaputra, Jamuna, Padma and Meghna – along with their numerous tributaries and distributaries make Bangladesh a land of rivers. The morphology of the rivers is highly dynamic since the landmass is composed of recent deltaic deposits. Erosion and accretion dominate the morphological process in the River Systems and Estuaries Hotspot (figure 2). During the monsoon, extensive overbank spills, bank erosion and bank-line shifts are typical regular phenomena, particularly along the banks of the main rivers (figure 4). The gradual migration or shifting of channels/tributaries of the major rivers in Bangladesh amounts to between 60 m and 1600 m annually. In a typical year, about 2,400 km of the bank-line experiences major erosion. The present rate of river-bank erosion is about 1770 ha year\(^{-1}\) for the Jamuna, 1298 ha year\(^{-1}\) for the Padma and 2900 ha year\(^{-1}\) for the lower Meghna. The Jamuna river is widening over time through eroding its banks at an average rate of about 130 m year\(^{-1}\). This corresponds to a loss of about 70,000 ha in 23 years, while only 11,000 ha had been accreted. Changes in the river flow and sediment transport due to multi-faceted impacts of climate change are expected to increase the dynamics of these rivers even more. During 1973–2013, a total of 52,313 ha land has been accreted due to river-bank erosion [21]. The unpredictable shifting behaviour of the rivers and their encroachments not only affect the rural floodplain population but also urban growth centres and infrastructures. River-bank erosion is thus a serious hazard that directly or indirectly causes suffering of about one million people annually through loss of life and property and damage to public goods and infrastructure. In the dry period, reduction in river flow in the transboundary rivers causes water scarcity for irrigation, high abstraction but reduced recharge of groundwater, and difficulty
in navigation. Sediments from the river-bank erosion combined with sediment deposits from the mountains are also the causes of difficulties in the dry season for navigability of the rivers.

Erosion is also a dominant problem in the Chittagong Hill Tracts Hotspot (figure 2). This region is the only extensive hill area in Bangladesh; the hills rise steeply. In general, most of the rivers of this region are flashy in nature, and erosion occurs along the banks. Landslides are becoming a growing hazard that occur following intense and prolonged periods of rain, removal of topsoil and vegetation. Sometimes, landslides are even triggered by light rainfall since the local people have cut away mud from steep slopes, increasing the likelihood of landslides. Loss of forest and vegetation cover and unsustainable farming practices will intensify impacts of increased water runoff, soil erosion, landslides, and drying up of the water springs and streams in this hotspot as a result of climate change.

![Figure 4. River-bank erosion in Bangladesh (Source: Banglapedia, 2019[22]).](image)

3.4. Sea-level Rise and Salinity Intrusion
The coastal zone of Bangladesh covers about 20% of the country and more than 30% of the cultivable land. Sea-level rise and, consequently, salinity intrusion in the coastal zone are critical issues now in the country. The overall trend of sea-level rise in this zone was 6–21 mm year$^{-1}$ in the last 30 years [23]. Stocker [12] predicts the sea level rise of between 0.2 m and 1.0 m for low to high emission (RCP4.5 and RCP8.5) scenarios in 2100 for the Bay of Bengal. The rising sea level is accelerating intrusion of salinity front and causing an increase in salinity of both surface water and soil in the coastal estuary region of the River Systems and Estuaries Hotspot (figure 2). The total amount of salinity-affected land in Bangladesh was 83.3 Mha in 1973, which increased to 102 Mha in 2000 and 105.6 Mha in 2009 (figure 5) [24]. The salinity-affected land continues to increase over time. A mean increase of 26% in salinity by 2050, with an increase over 55% in the most affected areas, has been projected. The increasing saline area will cause scarcity of freshwater, waterlogging and loss in agricultural production. This will have consequences for coastal settlements (with possible migration to urban areas) due to loss of livelihoods, as well as for coastal economies, cultures and ecosystems. Climate change in the future
could thus have serious implications for the agriculture sector, health, and food security of the people in this region.

The urban population base has expanded rapidly from 9% to nearly 28% between 1974 and 2011, making Bangladesh a rapidly urbanizing country. The urban area is the most densely populated area in Bangladesh, averaging about 1590 people per square kilometer. Population concentration in urban areas together with the negative impacts of climate change will compound matters and increase strains and stress on service providers and disaster-risk managers in the urban centres. They will be unable to cope with the ever-growing in-migration of rural population into urban areas. Consequently, there will be increasing water-borne diseases, flash flood disasters, and a breakdown of infrastructure and communications.

Figure 5. Soil salinity in the south-west coastal region and the increase in soil salinity from 1973 to 2009 (Source: Salehin et al., 2018[25]).

3.5. Cyclones and Storm Surges

The low-lying areas of the coastal zone in Bangladesh are highly vulnerable to cyclones, which pose serious threat to lives and properties of the region. Nearly every year, cyclones hit the country's coastal regions in the early summer (April–May) or late rainy season (October–November). On average, a severe cyclone (26–34% inundation area) strikes the country every three years [26]. Across the coastal zone, tidal amplitude ranges from approximately 1.5 m in the west to over 4 m in the east and up to 8 m at spring tide near Sandwip [27]. The intensity of cyclonic storm surges and coastal inundation, induced by depth and extent of storm surge, are likely to increase with changing climate through rising sea level and temperature of the sea surface (table 4 and figure 6). The coastal zone of the country is currently one of the most disaster-prone areas of the world. So, the low-lying densely populated coastal areas will be at increased risk of storm surges. Accordingly, approximately 40 million people of 70 Upazilas (sub-districts) under 19 coastal districts of Bangladesh are under the direct threat of being homeless due to displacement. In the coastal estuaries, tidal fluctuations and storm surge cause salinity intrusion, loss of polders to storm surges, scarcity of freshwater, waterlogging, and loss in agricultural production. All these factors are the causes of negative health impacts and out-migration of the affected population due to loss of their livelihoods.
Table 4. Vulnerable areas in Bangladesh due to storm surge induced inundation and projected depth of inundation for a baseline scenario without climate change and one with climate change (Sarraf et al., 2011[28]).

| Inundation depth (m) | Baseline scenario (km²) | Climate change scenario (km²) | Change (%) |
|----------------------|-------------------------|------------------------------|------------|
| >1                   | 20,876                  | 23,764                       | +14        |
| 3                    | 10,163                  | 17,193                       | +69        |

Figure 6. High-risk inundation area for cyclone-induced storm surge by 2050 in extreme climate change scenario (Source: IWM, 2014[29]).

4. Summary and conclusions
Impacts of climate change are complex and already serious in Bangladesh. These are causing greater stress on vulnerable groups and stressed regions. Among the main sectors, agriculture is likely to bear the main burden of output losses. By 2100, climate change could impose costs on the Bangladesh economy that could be significantly higher than the estimated global average loss. The challenges arising due to the impacts of climate change in Bangladesh can be summarized in the following four major items.

i. Rainfall will be more intense and erratic during the monsoon than its current state. Such rainfall will result in: (a) higher river flows that will cause over-topping and breaching of embankments and widespread flooding in rural and urban areas and drainage congestion, (b) river-bank erosion resulting in loss of homes and agricultural land to the rivers and (c) increased sedimentation in riverbeds leading to navigation problem, drainage congestion and waterlogging.

ii. Rainfall will be lower and more erratic in the dry season than in its current state. This will cause lower river flows in the dry season, increase in droughts in the drought-prone regions of the country, and increased salinity intrusion in the drier months of the year.

iii. Sea level will rise remarkably. This will lead to submergence of low-lying coastal areas and saline water intrusion up coastal rivers and into groundwater aquifers, reducing freshwater...
availability and drainage congestion inside coastal polders. All these will severely affect agriculture of the coastal region.

iv. The frequency of severe tropical cyclones, with higher wind speeds and storm surges, will increase and lead to more damage in the coastal region.

The evidence on past losses makes clear that Bangladesh faces serious climate change challenges that have grave implications on welfare of the people. These implications concern reduction of welfare and quality of life from adverse consequences for loss of production and assets.

While the future trends of the impacts of climate change are becoming clear, there is a need for more quantified spatial–specific information, especially on future changes in extreme events. It is necessary to improve link among the science of climate change, climate scenarios and usage of knowledge. Such link can ensure that the adaptation plans are developed based on actual knowledge of climate change at national and local levels. The nation-wide climate vulnerability assessment is a key step in reviewing, summarizing and understanding the climate change vulnerabilities that people in different regions of Bangladesh are currently facing. This assessment in the six climatic hotspots (urban areas, flood-prone areas, drought areas, coastal areas, hill tracts and wetlands) is an essential step to establish an index. This will help decision-makers better understanding the vulnerabilities of different areas for planning, funding and implementing development interventions.

Bangladesh has recognized climate change as a challenge to its long-term development and has made significant efforts in adapting to climate change through the Bangladesh Climate Change Strategy and Action Plan (BCCSAP) 2009. The government spends 6–7% of its annual budget (≈US$ 1 billion) on climate-change sensitive activity [30]. The government has taken up a 100-year mega project, called Bangladesh Delta Plan 2100, to reduce the risks of climate change in the Jamuna–Padma–Meghna floodplains and ensure water safety, food security and sustained economic growth. This project involves 19 thematic surveys on river system management, impact of climate change, disaster management, and protection of environment and livestock.

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