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DEBATES OVER CLIMATE CHANGE AND EXTREME WEATHER EVENTS: BANGLADESH AS A CASE

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Abstract

Bangladesh is highly vulnerable to climate change along with the adverse impacts of climate change. This paper aims to reveal the debates about climate change and extreme weather events. It considers Bangladesh as a case to understand the debates, the impacts of climate change on people's livelihoods. This paper used secondary sources to select and scrutunize recent literatures about climate change, extreme events, the impacts of climate change on livelihood patterns and future trends. Increase of minimum and maximum temperature and average rainfall are evident in this country along with the future projection regarding increase of temperature and precipitation. As a result sea level will rise and flood events will frequently occur in the future. The intensity, severity and extent of flooding will also be higher in the near future. It is evident that the negative impacts of extreme events will bring difficulties and challenges for people living in vulnerable areas and consequently will cause a lot of damage and loss of life. That demands paying more attention to climate change and context based adaptation strategies and integrative policy.

Key words: Bangladesh, climate change, extreme weather events, scenarios, vulnerability

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1. Introduction

The debate as to whether extreme weather events are due to climate change or are just natural occurrences has been at the centre stage as captured in American Meteorological Society report (AMS 2012). For instance, the origin of the heat wave in Russia around 2010 was 'natural' as reported by one research group while another research group claimed that it was due to 'anthropogenic' (Peterson et al., 2012). Peterson et al. (2012) also argued whether extreme weather events related to climate change depend on the researcher's 'perception' and 'attribution'. Therefore, they noted that to attribute extreme weather events to climate change had 'medium level confidence'. They argued that anthropogenic reasons, to some extent, influence fluctuations of temperature, which can contribute to extreme precipitation on a global scale. Whether a weather event or climate change event is considered extreme or not depends on the context (Zwiers et al., 2012). It is important to use a threshold value to classify a weather event as extreme. For example, if a value is close to the maximum or minimum of a threshold value such as tropical cyclones, according to 'the Saffir-Simpon scale', then it can be considered as extreme. Zwiers et al. (2012) concluded, "Changes in extreme temperature and the intensification of extreme precipitation events are expected consequences of a warming climate".

Oldenborgh et al. (2012) described an unprecedented two-month flood event in Thailand in 2011. The flood caused large economic losses and affected the livelihoods of many people. However, flood events are common in the country as well. They tried to investigate whether the flood event was due to climate change or other non-climatic factors involved with the devastating flood event. They

conducted statistical modeling and used climate models to explain the variability of precipitation, concluding that there was no statistically significant variation of rainfall in both the mean and variability in the country. Nevertheless, they projected that the mean and variability of precipitation would increase the 'frequency of very active monsoons' and 'probability of extremes' in the future. Oldenborgh et al. (2012) concluded that changes in hydrography and increased vulnerability, and changing agricultural land for industrial usage and reservoirs are also significant factors involved in extreme weather events such as floods, cyclones, etc. Adger et al. (2005) noted that the maximum number of disasters occurring in coastal areas is related to extreme weather events (e.g. floods, storm surges, etc). The impacts of extreme events are more severe due to the increase in human activities affecting climate change (Adger et al., 2005) such as glaciers melting causing sea levels to rise.

Bangladesh is highly vulnerable for climate change. Floods, cyclones and droughts are common extreme weather events in Bangladesh (Agrawala et al., 2003). Around the globe, majority of flood events are in South-Asia (39%). These events increase loss of life and economic loss (Dutta et al., 2004). Increasing adverse impacts of climate change in Bangladesh will make life difficult for people who live in vulnerable areas. Glaciers melting in the Himalayas, monsoon precipitation and intensity of cyclones will increase flood risk (Huq, 2002). Approximately 30 million people live in these areas, which are highly vulnerable to extreme floods in Bangladesh (Streatfield and Karar, 2008).

The paper aims to discuss critically the debate about extreme weather events and climate change. It also tries to demonstrate climate change scenarios, different extreme weather events and their effects on people's vulnerability. This paper considers Bangladesh as a case whether weather events might be considered as extreme or not and how climate change related with human activities are linked with the occurrences of extreme weather events. It also discusses the impacts of climate change and vulnerabilities by focusing on the results mentioned in different literatures. Discussion of this paper will help researchers interested in the debate about climate change and extreme weather events, vulnerability and livelihoods to understand the complexities, relationships and their link to empirical evidences like Bangladesh.

2. Results

2.1. Climate change scenarios in Bangladesh

2.1.1. Past and present scenarios of climate change

Shahid et al. (2012) collected data on daily temperatures from 1961 to 2008 to study variation in temperature in Bangladesh using a 'diurnal temperature range' (DTR). They found an increase of minimum and maximum temperature per decade for the country. The increasing rate for minimum and maximum was 0.15°C and 0.11°C respectfully. Although the rate was higher for the minimum compared with maximum the difference between the two rates is not significant to have caused an average change in DTR (Shahid et al., 2012).

There is also evidence of the reduction of DTR and increase of minimum temperature worldwide (Adger et al., 2003; Vlad and Toma, 2017). Fig. 1 shows an increase of minimum and maximum temperature for the studied periods in Bangladesh. Shahid et al. (2012) found that Bangladesh's temperature has increased with more winter warming compared with summer warming and an increase of temperature at nighttime compared with no changes in the daytime. They also observed that in Bangladesh, global warming would change rainfall patterns and consequently the diurnal temperature range (DTR) in future. Therefore, they argued, "it is not possible to come to a conclusion about impact of global warming on the climate of Bangladesh".

Shahid et al. (2012) also calculated the minimum and maximum temperature for a number of months. Fig. 2 shows that the minimum and maximum temperature was lowest for January.

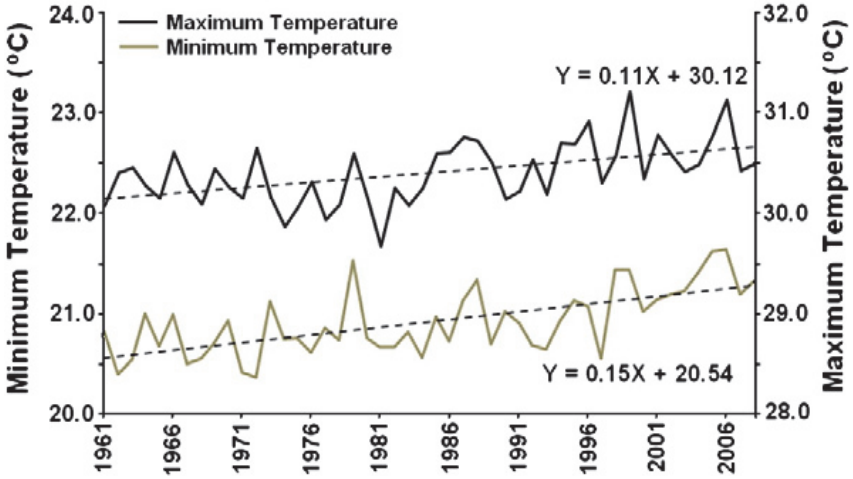


Fig. 1. Mean of maximum and minimum temperature (1961-2008), Bangladesh (adapted upon Shahid et al., 2012)

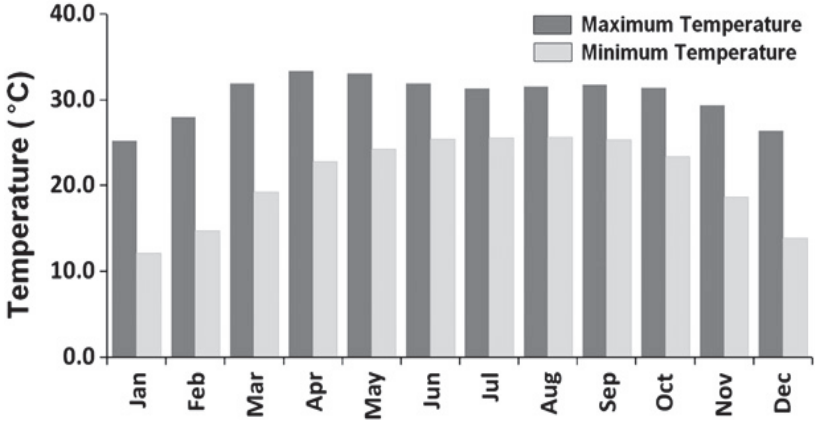


Fig. 2. Monthly minimum and maximum temperature in Bangladesh (adapted upon Shahid et al., 2012)

The highest maximum temperature was in April and May but the highest minimum temperature was between June and September. The figure is like a bell-shaped curve for minimum temperature with a wave-like fluctuation of maximum temperature from January to December in Bangladesh. According to Shahid et al. (2012), the average minimum and maximum temperatures are 19.2°C and 22.0°C during winter and, 29.7°C and 31.3°C during summer respectively. The temperature difference between the summer highest and winter highest is 9.3°C and the difference between summer lowest and winter lowest is 10.5°C.

Fig. 3 shows that the monthly mean rainfall is highest in July and is above 500mm. The percentage of the highest annual rainfall was about 25 percent and it was the same in July. The monthly mean and percentage of annual rainfall is lowest in December and January. The maximum percentage of annual rainfall occurs in June, July and August in the country. Calculation from collected data from 1969 to 2003 of average annual rainfall conducted by Shahid and Khairulmaini (2009), shown in Fig. 4, reveals fluctuations of average annual rainfall from year to year and the minimum average rainfall was in 1972 (about 2000mm) and maximum average rainfall was in 1991 (about 3200mm). However, the average annual rainfall (about 3000mm) was relatively the same for the period between 1999 and 2000. This indicates an increase of annual rainfall in the recent years and a high spatial and temporal variation in Bangladesh (Shahid and Khairulmaini, 2009). Jentsch et al. (2007) emphasize the consideration of temporal variation and statistical extremity concerning historical data such as a large deviation from the median of probability distribution (e.g. changes in minimum or maximum temperature, precipitation). For instance, they claimed changes in the duration of longest drought periods (e.g. magnitude of events) to be extreme events and regular changes in means of annual precipitation to be gradual trends. Mirza (2003) concluded that climate change may increase the vulnerability, frequency and magnitude of extreme weather events in the future in developing countries (e.g. floods, cyclones in Bangladesh).

He suggested that vulnerable countries to extreme weather events due to climate change should incorporate the likely social and economic impacts of extreme events into their analysis, planning and policies. Incorporation of training and programmes to reduce vulnerability to extreme events can enhance people's understanding about the impacts of extreme weather events especially in vulnerable areas like Bangladesh (Klein et al., 2007; Sundblad et al., 2007).

Patt et al. (2010) noted that there is no study by considering human losses to extreme weather events, as an indicator for vulnerability and how socio-economic development and climate change would affect vulnerability and extreme events. They claimed that more disaster-prone countries will have higher average human losses and vulnerability may be higher in the next few decades. This study conducted in least developed countries suggested counting socio-economic factors in the consideration of vulnerability coming from extreme weather events, because of climate change. The extreme climate change or extreme weather events lead to economic loss and even loss of life. Tompkins (2002) includes social, economic and environmental factors to categorize weathers events as extreme. He considers loss of life; insurance costs and treats to habitat in the analysis of extreme weather events from normal weather events. In the consideration of loss of life, developing countries like Bangladesh would suffer from the extreme events. From 1970 to 2000, Bangladesh faced three deadliest events out of five top extreme weather events such as storm and flood in 1970, tropical cyclones Gorky in 1991 and cyclone 905B in 1999 (Tompkins, 2002). Table 1 shows the top ten natural disasters from 1980 to 2010 in Bangladesh in terms of number of affected people, number of deaths and economic loss. It shows that most people in the country were affected by floods over this period, with the maximum numbers being affected in 1988 and then in 2004. The maximum number of fatalities occurred in the storm of 1991. The highest level of economic damage resulted from the flood in 1998. In 2007, the country suffered its third highest number of deaths due to a storm and its second highest economic loss.

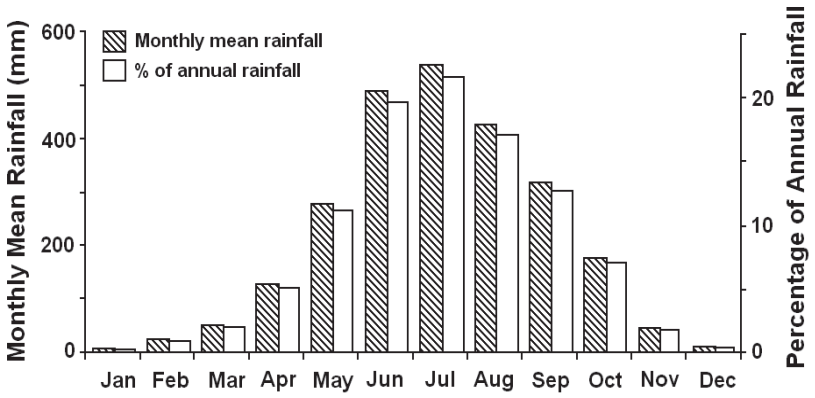


Fig. 3. Monthly mean rainfall and annual distribution of rainfall, Bangladesh (1969-2003) (adapted upon Shahid and Khairulmaini, 2009)

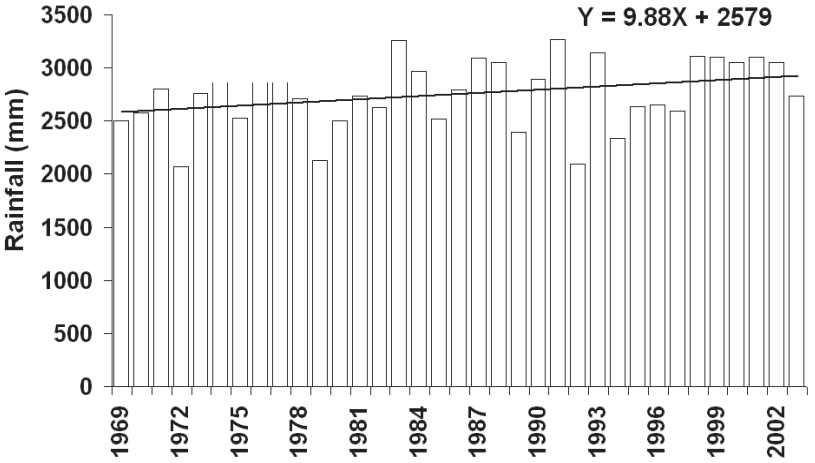


Fig. 4. Average annual rainfall in Bangladesh (1969-2003) (adapted upon Shahid and Khairulmaini, 2009)

Table 1. Top ten extreme climate change events or extreme weather events in Banglades (BCSI, 2014)

Events	*Year*	*Affected people*	*Events*	*Year*	*Deaths*	*Events*	*Year*	*Economic loss (US$)*
Flood	1988	45.000.000	Storm	1991	138.866	Flood	1998	4.300.000
Flood	2004	36.000.000	Storm	1985	15.000	Storm	2007	2.300.000
Flood	1984	30.000.000	Storm	2007	4.234	Flood	2004	2.200.000
Flood	1987	29.700.000	Epidemic	1982	2.696	Flood	1988	2.137.000
Drought	1983	20.000.000	Flood	1988	2.379	Storm	1991	1.780.000
Storm	1991	15.438.849	Flood	1987	2.055	Storm	1995	800.000
Flood	1998	15.000.050	Epidemic	1991	1.700	Flood	1987	727.500
Flood	2007	13.771.380	Flood	1984	1.200	Flood	2000	500.000
Flood	1995	12.656.006	Flood	2007	1.110	Earthquake	2004	500.000
Flood	1993	11.469.537	Flood	1998	1.050	Flood	1987	330.000

In general, we can say that a large number of people were affected and considerable economic damage suffered by floods in the last thirty years. But a large number of deaths in Bangladesh resulted from storms (see Table 1).

2.1.2. Future trends of climate change for Bangladesh

SCENGEN (a spatial climate-change scenario generator) estimates a global mean temperature and the projection for Bangladesh are shown in Table 2. The Table 2 shows increase of global mean temperature and a steady increase in temperature and precipitation for Bangladesh. According to Smith et al. (1998), more than 80 percent of annual precipitation (2300 mm) in Bangladesh falls during the monsoon period. Precipitation will increase during the summer monsoon since air over the land will be warmer than air over the ocean. Consequently, it will deepen the low-pressure system over land and enhance the monsoon (Agrawala et al., 2003). The major cause of global warming is the increase of regular emission of the greenhouse gases (e.g. carbon dioxide, carbon monoxide, methane, chlorofluorocarbons, nitrous oxide etc.). Shamsuddoha and Chowdhury (2007) mentioned

combustion of fossil fuels, deforestation, massive utilization of coal in China and increased cement production as the key factors responsible for increased carbon-dioxide emissions. Carbon-dioxide concentration is increasing at a rate of about 1.8 ppmv (parts per million) per year due to anthropogenic emissions (Shamsuddoha and Chowdhury, 2007).

Table 2. Future projections for temperature and precipitation (Bangladesh) (Agrawala et al., 2003)

Projections for future	***Year***		
	2030	***2050***	***2100***
Global increase in mean temperature	0.8°C	1.2°C	2°C
Increase in mean temperature for Bangladesh	1°C	1.4°C	2.4°C
Increase in mean Precipitation for Bangladesh	3.8 percent	5.6 percent	9.7 percent

According to the Keeling data (Manua Lua, oldest CO_2 measurement station) in May 14, 2013, concentrations of CO_2 is 399.58 ppm and the concentration is going to cross the 400-ppm level compared with 317 ppm in 1958 (http://keelingcurve.ucsd.edu/). The concentration is added about 2.1 ppm per year with the total CO_2 concentrations during the last ten years and it was about 0.7 in the late 1950s (http://researchmatters.noaa.gov/news/). The concentration will reach 450 ppm by the year 2040 (http://keelingcurve.ucsd.edu/).As a result, up to 55 million people in South Asia might be affected by flooding (SURVAS, 2006).

Streatfield and Karar (2008) argued that those on the coasts of India and Bangladesh would be particularly, exposed to flooding. In Bangladesh, around 30 million people are currently living in vulnerable coastal areas and islands in the Bay of Bengal (Streatfield and Karar, 2008). Church and White (2006) revealed that global sea levels rose about 17 cm in the last century. They also mentioned that the rate of increase in the last decade was almost double that of any other decade in the last century.

2.2. Climate change impacts and vulnerabilities in Bangladesh

2.2.1. Extreme weather events as a result of climate change

The possibility of glaciers melting in the Himalayas, greater monsoon precipitation and cyclones of increasing intensity may contribute to greater flooding in the future. Climate change in Bangladesh has brought changes to the levels of precipitation, annual mean temperature and sea levels. For instance, annual mean temperature increased at the rate of 0.0037°C during the period between 1961 and 1990 but the rate almost doubled to 0.0072°C during the period 1990-2000.

Over the last century, Bangladesh has warmed by about 0.5°C and sea levels have risen by 0.5m in the Bay of Bengal (Bangladesh Unnayan Parishad (BUP), 1993). As a result, low-lying lands will be inundated by floods. The intensity and extension of inundation is likely to increase in the near future in Bangladesh (Huq, 2002; Mcgranahan et al., 2007). Higher temperatures will result in more glaciers melting and an increasing runoff from the neighboring Himalayas into the Ganges and Brahmaputra rivers. Temperatures in the Himalayas (where the glaciers are located) are rising rapidly. Consequently, this will contribute to snow melting and floods coming to vulnerable areas in the country (Agrawala et al., 2003; Cruz et al., 2007). In addition, IPCC (2001) estimated that a 5-10 percent increase in wind-speed will magnify storm surges and coastal flooding, and an increase of associated precipitation will intensify flooding in the country. Ali (1996) calculated the effect of the 1991 cyclone with a 2°C increase and a 0.3 m sea level rise. Ali (1996) mentioned that a 1.5m higher storm surge would inundate 20 percent more land than in 1991 in the country.

Fig. 5 shows historic cyclone events that occurred in Bangladesh from December 1901 to November 2010. Cyclones occurred 12 times in the first half of the last century. Nevertheless, cyclones occurred 31 times in the second half of the last century. Cyclone events occurred almost 2.5 times higher in the second half of 20th century compared with the first half of the century. Table 3 shows information on storm surge height and wind speed. The maximum storm surge height was 7.6 meters April 1991. However, the maximum wind speed was in May 1997.

Only one cyclone event occurred in the last decade but the storm surge height and wind speed was relatively high. Karim and Mimura (2008) concluded that a 2°C sea surface temperature rise and 0.3m sea level rise in Bangladesh would result in the area at risk of flooding due to storm surges increasing by 15.3 percent. They also found that within 20km of the coastline, the depth of flooding would increase by 22.7 percent. 22 percent of exposed coast (5690 sq km) is a high-risk zone where depth of flooding might be 1m or more (Karim and Mimura, 2008).

Table 3. Cyclone events with maximum wind speed and surge height in Bangladesh *(PCB, 2009)*

Cyclone event	***Maximum wind speed (Kph)***	***Surge Height (m)***
December 1981	167	4.55
November 1983	135	1.5
May 1985	154	4.55
November 1988	161	4.4
April 1991	225	7.6
April 1994	210	4.85
May 1997	230	4.44
May 1998	150	2.44
November 2007	220	4.5

Flooding is very common in Bangladesh. Two-thirds of the country can be inundated during extreme flooding years (Mirza, 2002). Floodplains of major rivers (e.g. Ganges, Brahmaputra and Meghna) cover around 80 percent of Bangladesh and 20 percent of the lands are inundated due to spilling of the rivers each year during the monsoon period (June-September). Monsoon floods are due to extreme storms, which cause the big rivers to overflow. As a result, maximum water levels are usually higher than the predicted tides. Both coastal flooding (from sea and river water), and inland flooding (river/rain water) will increase in the near future in the country (Agrawala et al., 2003). Fig. 6 shows historical extreme climate change or extreme weather events and illustrate that the number of flood events occurred in Bangladesh were high. From 1951 to 2010, Bangladesh faced 51 flood events.

During the last decade, flood events occurred very frequently. After independence of the country in 1971, the country faced nine flood events in 1970s, 1980s and 1990s respectively. Ten flood events occurred in the immediate last decade (Fig. 6).

In the last decade of the previous century floods of 1998 covered about 70 percent of Bangladesh. Most of the population and the economy were badly affected by the regular flooding. Fig. 7 shows the year of highest area coverage in different decades in Bangladesh. Flood events in 1990s and 2000s covered more than 60 percent area of the country. It was almost doubled in 2000s compared with 1980s and 1970s. That indicates that flood events in the country will affect a large part of Bangladesh and facing the adverse impacts of flood events will be a big challenge in coming decades.

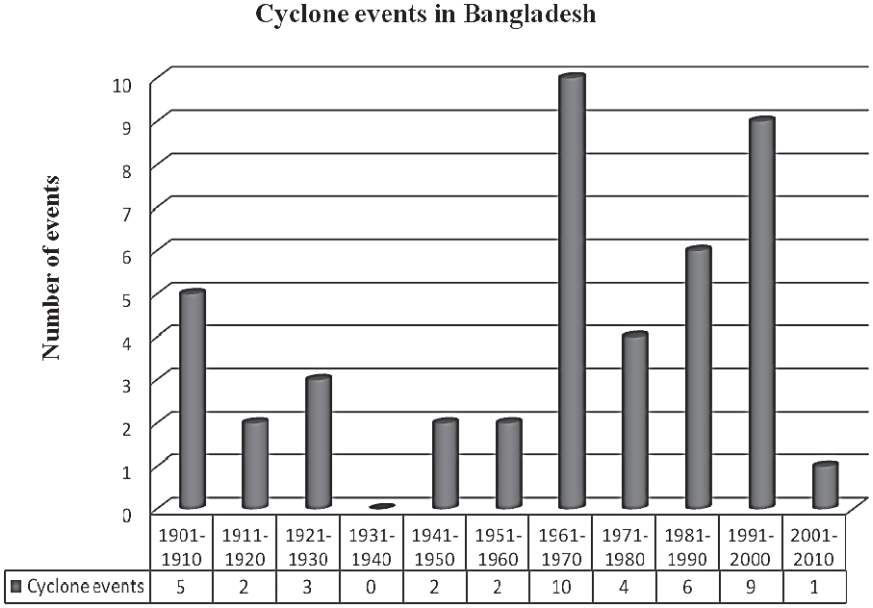


Fig. 5. Cyclone events in Bangladesh (1901-2010) (PCB, 2009)

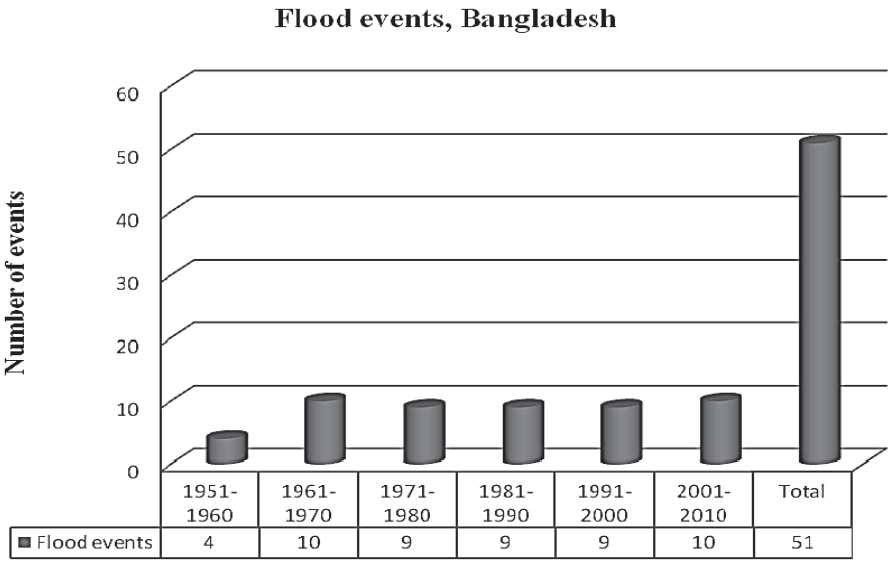


Fig. 6. Historical extreme weather events (floods) in Bangladesh (FFWC, 2012)

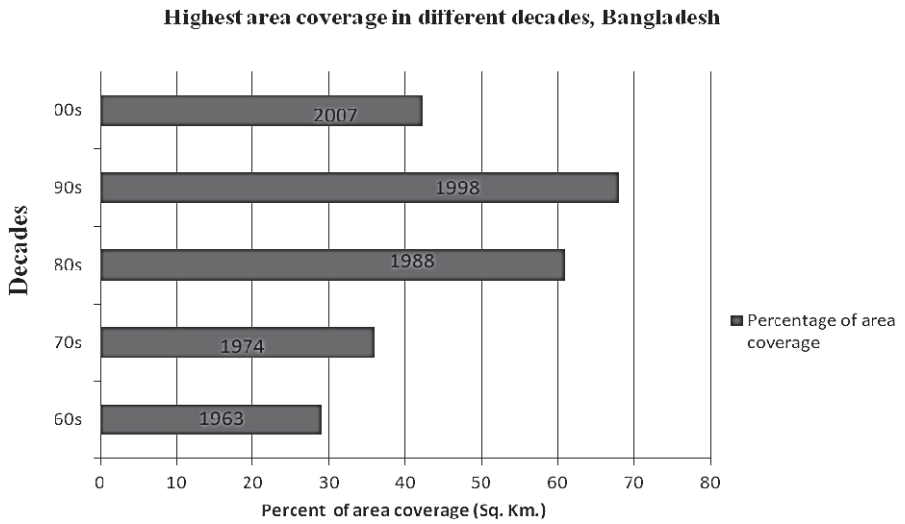


Fig. 7. Year of highest area coverage by flood events in Bangladesh (Adapted upon PCB, 2009)

2.2.2. Vulnerability and coastal populations

Dutta et al. (2004) argued that the majority of floods occur in South-Asia (39 percent) and in South-east Asia (30 percent). However, very few countries in South-Asia and South-east Asia have planning and mitigation strategies to deal with the consequences of climate change. In the case of Bangladesh, those living on the coast are finding their lives more difficult due to the increasing adverse impacts of climate change (Adger et al., 2005). 20 percent of those vulnerable to climate change directly depend on coastal and marine resources for their subsistence (Bangladesh Bureau of Statistics (BBS), 2003). People living in coastal area do not have enough access to education, health facilities and media information. Living standards and life expectancy are low comparing with the national level. Nevertheless, 28 percent of Bangladesh's population lives in areas vulnerable to climate change (Agrawala et al., 2003; Dutta et al., 2004). The coastal areas of Bangladesh have already faced salinity problems. This would be exacerbated by climate change and sea level rise. Salinity problems have affected agricultural activities and cropping intensity. The anticipated sea level rise would increase salinity and exacerbate these existing problems. Under these conditions, food production would be significantly reduced (Cline, 2007; Huq and Asaduzzaman, 1999).

Huq et al. (1995) estimated that 11 percent of the country's population lives in the area threatened by a 1 m sea level rise and in the future more people will be at risk from flooding due to coastal storms. Huq et al. (1995) claimed that since most of the country is less than 10m above sea level. It is very important how Bangladesh as a developing country adapts to its vulnerabilities, since the potential cost is substantial. The country does not have adequate finance and most of the country's people are poor and live in vulnerable areas (Huq et al., 1995). Poor people live in areas more vulnerable to extreme weather events and they have little capacity to adapt with the extreme events such as flood cyclone etc. Their livelihoods depend on ecosystem services. But extreme events threaten their livelihoods, food intake and health. It also affects the schooling of poor children during extreme weather events. Children help their family with household tasks. As a result, children give less time for schooling (PCB, 2009). A study in Bangladesh conducted by Paul and Routray (2010) found that flooding brings effects not only on the environment but also on people's socioeconomic conditions such as income, education, occupational structure etc.

2.3.3. Climate change and land degradation

It is argued that an increase in temperature results in greater crop yields in Bangladesh (Lal et al., 2001). On the other hand, Agrawala et al. (2003) estimated that an area of land producing 14,000 tons of grain would be lost due to sea level rise by 2030, and an area producing 252,000 tons of grain would be lost by 2075 in eastern Bangladesh. The country is losing good quality agricultural land at a rate of approximately 80,000 ha annually due to expansion of towns and cities into agricultural areas. Land is being continuously degraded and lost for erosion, salinity and inundation. Evidence shows that at least 86,000 ha of land was lost due to river/estuarine erosion during the period 1973 to 2000 (MES, 2001). Seventy percent of the land of Barisal and Khulna are affected by salinity causing a reduction of agricultural productivity. Fifty percent of coastal lands are subjected to inundation of varying degrees due to climate change and global warming (Ahmed, 2011). Ahmed (2011) mentioned different economic activities in coastal areas. Salt production continues to increase and use precious land to meet the ever-growing demand. In 2003/2004, 0.9 million tons of salt were produced from 24,900 ha of land in coastal areas. Coastal livelihoods are largely based on agricultural crops; the net cultivable land is 1.95 million hectares (Ahmed, 2011). In addition, fisheries contributed 5.23 percent of the GDP of Bangladesh in 2002/2003. Shrimp farming grew rapidly over the

last 30 years in coastal areas (Alam and Phillips, 2004).

However, adverse impacts of climate change also depend on geographic locations. Some places such as coastal areas and active floodplains are more vulnerable to the effects of climate change (Ericksen et al., 1997). Ericksen et al. (1997) argued that the rural landless and unemployed poor usually face the adverse effects of natural disasters. They are sometimes forced to relocate to other risky rural areas or urban slums. The vulnerable coastal areas make a large contribution to the country's economy, environmental conservation, livelihoods and tourism. But, the contributions from coastal areas are being hindered due to the adverse impacts of climate change.

3. Vulnerability, climate change risk and initiatives in Bangladesh

3.1. Vulnerability dimensions of climate change

Smit and Pilifosova (2001) mention vulnerability as a subjective concept. They also define vulnerability in terms of exposure, sensitivity, and adaptive capacity. However, the sensitivity and adaptive capacity of an affected community extensively relies on socio-economic conditions and cultural contexts. For instance, income generating sources, social inequality, health status and access to health facilities, insurance and social security system are significant contributors in the understanding of vulnerability for a community.

Moreover, it is very difficult to measure vulnerability, since it depends on different socio-economic characteristics (e.g. income, education, ethnicity, occupation) of the population living in vulnerable areas and the nature of the destructive events (Marandola Jr. and Hogan, 2006). Thus, different groups of people have different levels of vulnerability and those who are vulnerable are affected in different ways and to different degrees (Wisner et al., 2004; Smit and Wandel, 2006; Martínez-Graña and Gago 2018). Vulnerability to climate change is a complex concept that depends on changes in the environment, the diversified actions of different stakeholders, interactions between environmental and socio-economic systems and cultural traditions (Dolan and Walker, 2004). Agrawala et al. (2003) pointed out some factors to explain climate change vulnerability. The factors are discussed in Table 4.

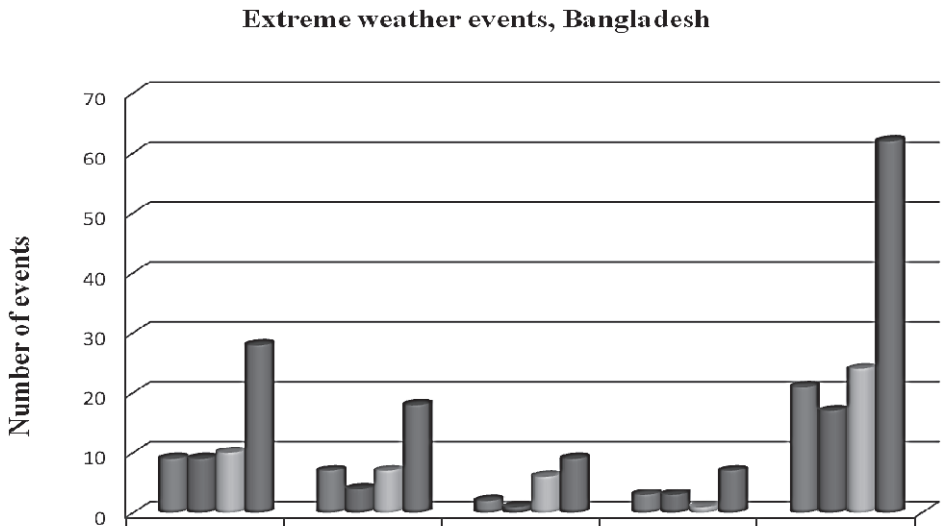
3.2. Climate change Risk and evidences

Climate change (temperature increase, sea level rise and precipitation) has a relation to natural hazards like cyclones, floods and droughts. Shahid (2012) shows that heavy rainfall days and hot days has increased. He considers data from 1958-2007. He mentions the days with greater than 20 mm rainfall as heavy rainfall and, with greater than 30°C maximum temperature as hot days. He finds that heavy rainfall days and hot days has increased with an amount of 1.2 days per decades and 1.16 days per year respectively. Bangladesh would face more rain-related floods resulting from an increase of annual rainfall and heavy rainfall events. It is evident that extreme events such as floods etc have increased with the increase of rainfall and temperature in the last decade in the country (Shahid, 2012).

Fig. 8 shows the number of different extreme weather events that occurred in the last few decades in Bangladesh. In the 1980s and 1990s the country faced drought events, but these occurred only once in the last two decades. The number of tornados has increased in the last decades, whereas the number of cyclones has fluctuated. The number of flood events also increased in recent years. However, the total number of extreme weather events has remained steady over the last thirty years (see Fig. 8). But number of flood events was highest in the last two decades compared with 1980s and 1990s. Coastal areas will be most affected by cyclonic storms and flooding. The rest of country's area will be affected by flooding. "Bangladesh has about 2.8 million ha of land affected by salinity and poor-quality water. The total area includes deltaic floodplains and offshore islands and is about one fifth of the total area of Bangladesh"(http://www.banglapedia.org/HT/S_0044.HTM).

Table 4. Factors involved in understanding climate change as extreme

No	*Factors*	*Explanations*	*Sources*
1	Certainty of impact	Using available knowledge of climate change in terms of changes in temperature and sea level rise can contribute to assess the likelihood of the impacts of climate change. According to IPCC (2001), decreasing difference between high maximum and high minimum temperature, irregular and frequent fluctuations in rainfall patterns, more intense droughts, increased cyclone wind speeds will occur in the near future.	Houghton et al. (2001)
2	Timing	It considers how impacts to a particular sector become severe or critical. Ranking of impacts depend on subjective ranking. It also depends on the manifestation of impacts, whether it appears in the first or the second half of this century.	
3	Severity of impact	This factor considers the intensity of impacts from climate change. It regards the sensitivity of a sector to climate change.	
4	Importance of the sector	This factor includes how climate change is critical to socio-economic dimensions and culture. For instance, it also concerns what proportion of populations, wealth and properties are affected by climate change.	



	Flood	Cyclone	Tornado	Drought	Total
80s	9	7	2	3	21
90s	9	4	1	3	17
00s	10	7	6	1	24
Total	28	18	9	7	62

Fig. 8. Total numbers of different extreme climate change events or extreme weather events (Bangladesh) (FFWC, 2012; PCB, 2009)

Flood events occur approximately once every ten years and inundate about 37 percent of land. The percentage of land was covered five times by flood events in the last thirty years but it was three times in the last ten years (PCB, 2009).

3.3. Climate change initiatives

Climate Change Cell (CCC) was established in the Department of Environment, Ministry of Forests and Environment, Bangladesh in 2004 under the Comprehensive Disasters Management Programme (CDMP). The Cell prepares technical papers for the Ministry and publishes online newsletters. It also conducts research about climate change adaptation, national capacity building and maintain data about climate change. Activities of the Cell are supervised by a Technical Working Group and Director General of department of Environment is the Chair of the group. The fourth assessment of the Intergovernmental Panel on Climate Change (IPCC) reports that Bangladesh is at risk of increasing salinity of its groundwater as well as surface water along the coast due to higher sea levels as a direct impact of global warming. Sea level rise could flood the residences of millions of people living in low-lying areas, especially coastal areas in Bangladesh. According to IPCC, Bangladesh is already showing evidence of the adverse impacts of global warming and climate change: summers are hotter, monsoons and rainfall are becoming irregular, river flow and inundation is increasing during the monsoon, and the frequency and intensity of floods is increasing. From the recent fourth assessment report published in 2007 by the Intergovernmental Panel on Climate Change (IPCC), Climate Change Cell under the Department of Environment, Bangladesh (2007), summarized the following evidence of climate change in Bangladesh:

1. "The average temperature has registered an increasing trend of about 1°C in May and 0.5°C in November during the 14-year period from 1985 to 1998, an overall. The annual mean rainfall exhibits increasing trends in Bangladesh. Decadal rain anomalies have been above long-term averages since the 1960s. 2. Serious and recurring floods have taken place during 2002, 2003, and 2004. The number of cyclones originating from the Bay of Bengal has decreased since 1970, but the intensity of each cyclone has increased. 3. The frequency of monsoon depression and cyclone formation in the Bay of Bengal has increased. 4. Water shortages have been attributed to rapid urbanization and industrialization, population growth and inefficient water use. These are aggravated by changing climate and its adverse impacts on demand, supply and water quality. 5. Salt water from the Bay of Bengal is reported to have penetrated 100 km or inland along tributary channels during the dry season. 6. Precipitation decline and droughts have resulted in the drying up of wetlands and the severe degradation of ecosystems". (http://www.climatechangecell.org.bd/publications/13ccbd.pdf)

3.4. Extreme weather events, poverty and vulnerability

Brouwer et al. (2007) examined vulnerability and adaptation to flooding in Bangladesh. The study looked at people living in the floodplains along the River Maghna. The study found a relationship between poverty, vulnerability and adaptive capacity. For instance, the poor live closer to the river, face higher risks of flooding and have less preventive

measures against floods and less access to disaster relief. The wealthy people who live further from the river have more income sources and lower damages and costs arising from flooding. The poorest households, who live close to the river, depend on unreliable sources such as fishing for their livelihoods, face high damage from flooding and usually have few opportunities to diversify their income sources and recover their damages. It can be said that those of low socio-economic background are most vulnerable and live in areas with high risk of natural disasters.

According to the CCC (2007), a major concern for Bangladesh is helping the increasing number of victims of the effects of climate change who must seek refuge due to the loss of their homes due to river erosion, coastal erosion and permanent inundation. In the years 1982–1992 over 106 thousand hectares of land eroded along the three major rivers of Bangladesh (Ganges, Brahmaputra and Meghna) and about 350 thousand people were displaced, suffering severe economic and social consequences. As a result, climate change may undermine efforts towards reducing poverty and could prevent achievement of the Millennium Development Goals (MDGs). The OECD and the World Bank estimate that 40 percent of future overseas development assistance to Bangladesh will be for climate change risk and sensitivity. CCC (2007), mention the likely adverse impacts on water resources, agriculture and forestry, food security, human health, infrastructure (e.g. transport), homes and livelihoods. Regarding the impacts of extreme climate change events and poverty, Ahmed et al. (2009) found that poor people especially in developing countries including Bangladesh would face severe impacts of extreme events. Extreme events would even worsen poverty level of people living in vulnerable areas and, significantly bring impacts on agricultural production such as declining of grains production. As result, it would affect food price and supply in poor countries. Different groups of people face the adverse impacts of extreme events at different levels such as urban poor who are dependent on wage labor would be affected more from the rise of food rice (Ahmed et al., 2009).

3.5. Climate change and health complexities

It is already evident that climate is changing. Impacts of extreme weather events including floods, heat waves due to climate change would bring significant effects on human health such as respiratory, allergic problems, and indirectly, anxiety, depression etc. (Frumkin et al., 2008). Climate change related health impacts such as diarrhea and malnutrition are already happened in Bangladesh. The combination of higher temperatures and increased summer precipitation will create the conditions for a greater intensity and spread of many infectious diseases (Agrawala et al., 2003). An increase in health risks is likely due to the rise in flooding and cyclones in Bangladesh (Agrawala et al., 2003).

The causes of outbreaks of infectious diseases are complex. There is no simple relationship with increasing temperature or changing precipitation. Nevertheless, as a whole, climate change is expected to increase the risks to human health especially for children and elderly people (McMichael et al., 2006).

4. Discussions

Many scholars argue that extreme weather events may be related to climate change. Some claim the occurrence of extreme events to be natural and some consider extreme events anthropogenic. However, the relation between climate change and extreme weather events depends on the researcher's perception and how they interpret an event (Peterson et al., 2012). Zwiers et al. (2012) mention the consideration of extreme weather events as extreme depends on the context and they suggest using a threshold value. If calculated values deviate greatly from a threshold value then an event may be considered extreme such as variation in maximum and minimum temperature and precipitation.

However, Oldenbrgh et al. (2012) mentioned the flooding in Thailand in 2011 as an example. They noted after performing statistical and climate change modelling that the occurrence of floods is normal and they found extreme flood events to be related to the mismanagement of land and policies related to the environment. Jentsch et al. (2007) also mentioned temporal variation and statistical extremity. For instance, Shahid and Khairulmaini (2009) found a high temporal and spatial variation concerning the annual rainfall in Bangladesh. Adger et al. (2005) suggested that climate change and human activities influence extreme weather events such as floods, cyclones, etc. in the case of Bangladesh, while Shahid et al. (2012) found an increase of minimum and maximum temperature and more winter warming, and annual increase of rainfall (Shahid and Khairulmaini, 2009). They also observed that the minimum has increased faster than the maximum. However, they were not able to draw any conclusion concerning the impact of global warming on the Bangladeshi climate. Moreover, understanding of socio-economic impacts of extreme weather events (Mirza, 2003) and considering human losses (Patt et al., 2010) enable an understanding of vulnerability especially in developing countries. According to IPCC (2001), the temperature increase in Bangladesh, compared with the global mean temperature will be higher and precipitation will increase during the monsoon season bringing more flooding to the country. The precipitation will increase during the summer monsoon. More than 80 percent of annual precipitation in Bangladesh generally falls during the monsoon period (Smith et al., 1998).

Bangladesh is a low-lying land country and floodplains occupy most of the country's land. There

are 64 districts in Bangladesh, 16 of which include coastal areas. The coastal zone is mostly dominated by agriculture. 35 million people live in coastal areas - over a quarter of country's total population. Most of the coastal people's livelihoods directly depend on coastal and marine resources. It is estimated that the coastal population in Bangladesh will increase to around 40-50 million by 2050 (Agrawala et al., 2003).

Flood events have a highly adverse effect on the economy of a country. Bangladesh is highly vulnerable for climate change. The country usually faces flooding and cyclones every year, since two-thirds of the country are less than 5 meters above sea level. IPCC (2001) projected that the intensity of cyclones may increase between 5 percent and 10 percent and precipitation rates may increase between 20 percent and 30 percent. Furthermore, the country will be affected by rising sea levels. It is estimated that sea levels in Bangladesh will rise between 30 and 100cm by 2100, while the IPCC Third Assessment projects sea level rise at a global level between 9 and 88 cm (IPCC, 2001). The global sea level rise may bring the worst impacts to coastal zones in Bangladesh. Mean sea level rise increases inundation and salinization of the low-lying deltaic coast and storm surges contribute to flooding and loss of life.

In 1991, a cyclone caused huge economic loss and loss of lives. The cyclone happened with an increase in temperature of 2°C and a 0.3 m rise in sea level. Considering the 1991 cyclone event in Bangladesh, Ali (1996) estimated that a 1.5 m higher storm surge would inundate 20 percent more land. The entire coastal zone is prone to violent storms and tropical cyclones during the pre-monsoon and post-monsoon season. The massive loss of life from cyclones is due to the large number of coastal people living in poverty, poorly constructed houses, an inadequate numbers of cyclone shelters, poor cyclone forecasting and warning systems etc (Gray, 1968).

Coastal resources are also at high risk from climate change when the following factors are considered: the certainty of impact, severity of impact and importance of resources. Coastal resources are vulnerable because they are at low elevation especially the Sundarbans. According to different estimates, sea level will rise in Bangladesh and will affect the mangrove systems, change the ecosystem of the Sundarbans and damage the livelihoods of those who depend on coastal resources for their subsistence. Smith et al. (1998) estimated that a 25 cm sea level rise would result in a 40 percent loss of forests in the Sundarbans and the displacement of ten million people (Huq, 2002).

A study conducted by O'Neill (2009) found that an increase of 1 percent in the rate of population growth is associated with a 1 percent increase in carbon emissions while controlling for variables such as economic growth and technology. UNDP (2007) estimated that all future population growth will happen in the developing world and that the world will become more urban, with the proportion of urban dwellers increasing from 48 percent in 2005 to about 70 percent in 2050.UNPD (2007) also predicts the proportion worldwide elderly (aged 60+) will increase from 10 percent in 2005 to 22 percent in 2050. Moreover, the poorest countries and population groups will be most affected by climate change and attention to adaptation strategies are not adequate in these countries. Since population growth rates are high in poor countries, an increasing number of people will live in climate change vulnerable areas (Haq, 2013). This will cause difficulties in the country's ability to provide services such as schooling, employment opportunities, health and infrastructure. In addition, GSP (2002) revealed that populations who are socially disadvantaged are also at greater risk and vulnerable. These populations are usually the poorest group of people, especially women and children. They have limited capacity to protect themselves from potential environmental hazards (e.g., air pollution and water pollution, land erosion, biodiversity loss, declining water levels and climate change events) both now and in the future.

Jiang and Hardee (2011) argued that climate-related hazards (cyclones, droughts, floods, and landslides) are largely concentrated in certain areas. The poor are at significantly higher risk of climate-related hazards. They mentioned that low-income populations have been affected by more climate-related hazards (e.g. droughts, floods and landslides) than high or middle-high income populations, who have only been affected by cyclones. They predicted that future climate change would continuously and increasingly affect poor and vulnerable populations. They claimed that poor and vulnerable populations are more exposed to climate change risks since they mostly depend on the climate for survival and usually have fewer resources to cope with the adverse impacts of climate change (floods, cyclones, salinity etc).

Jiang and Hardee (2011) argued, "The relation between population change and climate change is complex and anthropogenic effects on emissions are the product of a range of forces, including economic growth, technological changes and population growth". In addition, they stated that the concept of human vulnerability is also complex and is influenced by a wide range of factors (e.g. demographic changes, geography, infrastructure, access to various forms of capital) (Haq and Ahmed, 2017). Therefore, they claimed that climate change models are still limited by not taking sufficient account of the influence of population dynamics on climate change and they suggest an incorporation of population factors into climate change adaptation strategies. The Poverty Reduction Strategy Paper (PRSP, 2004) includes the vulnerability to natural hazards in its policy plans. It emphasizes the implementation of adaptation strategies to reduce the poverty situation in Bangladesh. It argues that climate change related disasters could hamper national development. It is of great importance that

the adverse effects of climate change are minimized through macro level policies and 'practical actions' (Alvarez-Lajonchère et al., 2018) at national level that incorporate the mitigation and management aspects in development plans for the country.

5. Conclusions

Climate change is a major concern of Bangladesh. It is one of the most vulnerable countries. Climate of Bangladesh is changing rapidly. Climate change is related with the occurring of more extreme weather events in the country. In Bangladesh, climate change is a threat for the coastal populations as sea level is rising. In future, most of the areas of Bangladesh will be inundated by flooding because of climate change. The notion of climate change elucidated that temperature is increasing along with the frequent fluctuation of rainfall in Bangladesh.

In the coastal areas, environment is degraded due to salinity that affects the socio-economic conditions of populations. Furthermore, vulnerable populations suffer from health complexities as well as several diseases are brought out after the extreme weather events. During extreme weather events like floods, cyclones and tornadoes many people die and many are injured. Extreme weather events also foster the existing vulnerability and poverty that are evident in Bangladesh from several studies on vulnerable areas. However, it is noticed that research on climate change is initiated by several governmental and NGOs along with the individual researchers to find out 'rehabilitation solution' and the pathways of adaptation and mitigation of the impacts of climate change and extreme weather events. It is evident that climate is changing and it will change gradually in future.

Extreme weather events are related with climate change and anthropogenic reasons are responsible for rapid climate change. Because climate change has already brought different consequences including different extreme events. It would be worthwhile not to debate whether climate change is natural or occurred due to anthropogenic reasons and extreme weather events are related with climate change or not. Instead of that, I think more research on how to tackle and adapt the adverse impacts of climate change and extreme events would be more effective and smart way to face upcoming challenges in developing countries including Bangladesh.

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