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Spatial and temporal changes of climatic variables and its impact on natural disasters in Bangladesh

Meher Nigar Neema*, Md. Azit Siraj

Department of Urban and Regional Planning, Bangladesh University of Engineering and Technology, Dhaka-1000

Email address:
mnneema@yahoo.com (M. N. Neema), azit_siraj@yahoo.com (M. A. Siraj)

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Abstract: Bangladesh is confronted with a big challenge to mitigate the significant impact of climate change. Due to the climate change, Bangladesh has already experienced average maximum temperature rising, minimum temperature decreasing, rainfall, relative humidity and cloud coverage decreasing resulting frequent and severe floods, tropical cyclone, extensive river bank erosion and drought. This paper focuses mainly to identify the spatial and temporal changes of climatic variables namely temperature, rainfall, humidity and cloud coverage of Bangladesh using data from Bangladesh Meteorological Department (BMD), Bangladesh Water Development Board (BWDB) and Bangladesh Agricultural Research Institute (BARC) at 32 stations and also find out the adverse impacts of climate change especially on natural disasters of Bangladesh. To determine the climatic variability an inclusive meteorological estimation was carried out for the period of 2007-2011 and the results were compared with the period 1987-1991. The results of the climatic variability show that the average maximum temperature is increasing at a rate of 0.03°C per year but the annual minimum temperature is decreasing at a rate of 0.003°C per year. On the other hand, the annual rainfall, relative humidity and cloud coverage decreased by 0.63 mm, 0.013 percent and 0.007 respectively per year. For these climatic changes during the period 1970 to 2013, one hundred thirty four (134) major and minor cyclones hit the coastal regions of Bangladesh and almost two-third (88) of them hit in the period of 1992-2013 which is very alarming for our survival. On the other hand, it shows that the intensity and frequency of extreme flood events have significantly increased and the most extensive floods in the period 1954-2012 occurred after 1986 (1987, 1988, 1998, 2004, 2007) are considered by hydrologists to be at a size expected only once in every 20 years. The floods of 1987, 1988, 1998, 2004 and 2007 and cyclones of 1991, 1997, 2007 and 2009 are direct impact of climate change in Bangladesh.

Keywords: Climate Change, Temperature, Rainfall, Humidity, Cloud Coverage, Disasters

1. Introduction

Impacts of climate change can be characterized by increasing temperatures, rainfall, humidity changes and climate related extreme events such as floods, cyclone, droughts, sea level rise, salinity and soil erosion [1] and [2]. Intergovernmental Panel on Climate Change (IPCC) has reported in their fourth assessment report that global surface temperature increased 0.74 ± 0.18 °C during the last 100 years ending in 2005 (IPCC 2007). It is also noted that the rise of mean annual temperature will be 3.3 °C per century [3]. It is one of the biggest concerned not only for Bangladesh but also for the entire globe.

According to the third Assessment report of IPCC, south Asia is the most vulnerable region of the world to climate change impacts [4]. It also recognized that Bangladesh ranks high in the list of most vulnerable countries on earth. Because two-thirds of the land is less than 5 meters above the sea level and the country is susceptible to river and rainwater flooding, particularly during the monsoon.

According to the German watch Global Climate Risk Index 2013, Bangladesh ranked 4th out of 182 most affected countries by extreme weather events from 1992 to 2011 in the world [5]. It is also noted that, more than 530,000 people died as a direct consequence of almost 15,000 extreme weather events, and losses of more than USD 2.5 trillion (in purchasing power parity) occurred between 1992 to 2011 globally [5]. Once every three to five years, up to two-thirds of Bangladesh is inundated by floods that causes substantial damage to infrastructure, housing, agriculture, and livelihoods. Low-lying coastal areas are also at risk from tidal floods and severe cyclones. On average once every

three years, a severe cyclone makes landfall on the Bangladesh coastline, either before or after the monsoon, creating storm surges that are sometimes in excess of 10 meters. Crops and the livelihoods of the rural poor in low-lying coastal areas are also devastated by saline water intrusion into aquifers and groundwater and land submergence. In addition, seasonal droughts occasionally hit the northwestern region in Bangladesh.

The overall objective of this study is thus to characterize the spatial and temporal changes of climatic variables in Bangladesh using the measured data available from Bangladesh Meteorological Department (BMD) and Bangladesh Agricultural Research Council (BARC). The specific objectives of the study include:

1. Evaluation of changes in temperatures (maximum and minimum), rainfalls, relative humidity and cloud coverage in Bangladesh
2. Assessment of adverse impacts of climate change on frequency and intensity of natural disasters in Bangladesh.

2. Materials and Methodology

The study area of the current research encompasses the entire geography of Bangladesh, a South Asian developing country located between 20°34' to 26° 38' North latitude and 88° 01' to 92°40' East longitude with an area of 147,570 km^2. It is bordered on the west, north and east by India, on the south-east by Myanmar and on the south by the Bay of Bengal. In order to unfold the changes of climatic variables (temperature, rainfall, humidity and cloud coverage) over the years and find out the main causes of natural disasters of Bangladesh, the entire country was chosen as study area. The study has been conducted based on the secondary data which were collected from Bangladesh Meteorological Department (BMD), Bangladesh Agricultural Research Council (BARC) and from different literatures. Available climatic data have been collected from 32 BMD hydro-meteorological stations located all over the country. The climatic data were divided into two periods (each consists of 5 years) during 1987-1991 and 2007-2011. To determine the climatic variability during the last twenty years, a comprehensive meteorological evaluation was carried out in this study for the period 2007-2011 and the results were compared with that of period 1987-1991. Collected data from different sources were compiled, tabulated, analyzed using dedicated tools of Spreadsheet and GIS. Arc GIS 10.1 was used for mapping, analysis and comparison of collected information. The results of GIS and statistical analyses were also comprehensively presented in graphical and pictorial form.

3. Result and Discussion

3.1. Trends of Climate Change in Bangladesh

To find out the trend of climate change in Bangladesh, four incommensurable factors: 1) maximum and minimum temperature, 2) rainfall, 3) humidity and 4) cloud coverage are selected. A comparative study was conducted for the climatic change parameters for a period of twenty five years from 1987-2011 to appraise the impacts of climate variability on natural disasters because climate change adversely influences the rise in sea level. This in turn increases salinity intrusion, coastal flood etc over the years in Bangladesh. It has also been identified before climate change induced problems in coastal resources, freshwater resources, agriculture, human health, ecosystem and biodiversity [6]. Table 1 shows monthly climate records of two study periods. Annual climate records were used to map the spatial distribution of the climatic parameters.

Table 1. *Change in monthly and annual climatic parameters in Bangladesh [7], [8] and [9]*

Study Periods	Metrological Parameters	Average Monthly Result						
		JAN	FEB	MAR	APR	MAY	JUN	JUL
Existing (2007-2011)	Maximum Temperature(°C)	25.96	28.84	32.97	33.75	33.62	32.46	31.54
	Minimum Temperature (°C)	12.26	15.03	19.85	23.49	24.48	25.43	25.57
	Annual Rainfall (mm)	8.29	18.71	24.35	77.66	256.7	454.4	569.3
	Relative Humidity (%)	78.3	72.1	71.01	75.41	78.77	84.69	86.48
	Cloud Coverage	0.97	1.32	2.12	3.21	4.33	5.83	6.33
Previous (1987-1991)	Maximum Temperature (°C)	25.47	28.53	31.31	33.11	32.86	31.8	31.05
	Minimum Temperature (°C)	12.52	15.85	19.67	22.92	24.71	25.69	25.71
	Annual Rainfall (mm)	3.63	25.02	59.89	140.84	263.4	480.1	582.1
	Relative Humidity (%)	75.43	72.91	71.82	75.17	79.95	85.33	87.68
	Cloud Coverage	0.8	1.48	2.4	3.45	4.52	5.89	6.45
Changes (1987-2010)	Maximum Temperature(°C)	0.49	0.31	1.66	0.66	0.76	0.76	0.66
	Minimum Temperature (°C)	-0.26	-0.82	0.18	0.57	-0.23	-0.26	-0.14
	Annual Rainfall (mm)	4.66	-6.31	-35.2	-63.28	-6.69	-25.7	-12.8
	Relative Humidity (%)	2.9	-0.81	-0.81	0.24	-0.18	-0.64	-1.2
	Cloud Coverage	0.17	-0.16	-0.3	-0.24	-0.19	-0.06	-0.12
Annual Changes	Maximum Temperature(°C)	0.02	0.02	0.08	0.03	0.04	0.03	0.02
	Minimum Temperature (°C)	-0.01	-0.04	0.01	0.03	-0.01	-0.01	-0.01
	Annual Rainfall (mm)	0.23	-0.32	-1.78	-3.16	-0.33	-1.28	-0.64
	Relative Humidity (%)	0.15	-0.04	-0.04	-0.01	-0.01	-0.03	-0.06
	Cloud Coverage	0.01	-0.01	-0.02	-0.01	-0.01	0	-0.01

Table 1. *Continue*

Study Periods	Metrological Parameters	Average Monthly Result					
		AUG	SEP	OCT	NOV	DEC	Average
Existing (2007-2011)	Maximum Temperature(°C)	32.08	32.33	31.47	29.81	26.22	30.92
	Minimum Temperature (°C)	25.71	25.48	23.52	19.03	14.42	21.19
	Annual Rainfall (mm)	458.4	315.1	220.6	25.85	6.46	202.99
	Relative Humidity (%)	86.28	85.72	83.13	79.53	79.86	80.11
	Cloud Coverage	6.04	5.48	3.43	1.45	1.16	3.47
Previous (1987-1991)	Maximum Temperature (°C)	31.52	31.53	31.21	29.51	26.45	30.36
	Minimum Temperature (°C)	25.81	25.51	23.5	19.05	14.22	21.26
	Annual Rainfall (mm)	396.8	364.5	203.57	48.79	17.71	215.52
	Relative Humidity (%)	86.02	86.52	83.34	79.21	80.92	80.36
	Cloud Coverage	5.99	5.7	3.58	2.14	1.21	3.63
Changes (1987-2010)	Maximum Temperature(°C)	0.49	0.56	0.8	0.26	0.3	0.64
	Minimum Temperature (°C)	-0.1	-0.03	0.02	-0.02	0.2	-0.07
	Annual Rainfall (mm)	61.46	-49.4	17.03	-22.9	-11.3	-12.56
	Relative Humidity (%)	0.26	-0.8	-0.21	0.32	-1.06	-0.17
	Cloud Coverage	0.05	0.22	-0.15	-0.69	-0.05	-0.13
Annual Changes	Maximum Temperature(°C)	0.03	0.04	0.01	0.02	-0.01	0.03
	Minimum Temperature (°C)	-0.01	0	0	0	0.01	-0.003
	Annual Rainfall (mm)	3.07	-2.47	0.85	-1.15	-0.56	-0.63
	Relative Humidity (%)	0.01	-0.04	-0.01	-0.02	-0.05	-0.013
	Cloud Coverage	0	0.01	-0.01	0.02	-0.05	-0.007

3.2. Temperature

Temperature is an essential indicator of climate change because it has direct effect on the climate as well as different types of disasters and other adverse affects. For thirty-two stations, five-year average mean annual maximum temperature of Bangladesh was 30.36°C in the period 1987-1991 and about 30.92°C in the period 2007-2011 (Table 1) although it varies with elevation throughout the study area. On the other hand, the average mean annual minimum temperature is slightly decreased than previous period. The average mean annual minimum temperature was 21.26°C in the period 1987-1991 whereas it decreased to 21.19°C in the period 2007-2011. Table 1 also shows that the average mean maximum annual temperature increased by 0.64°C with the annual temperature change of 0.03°C from the last twenty years and the average mean minimum temperature decreased by 0.07°C. But it was reported that the increase of temperature about 0.5° C during past 100 years in Bangladesh [10]. The month April was found to be the hottest and driest in both periods where in the period 2007-2011, the annual maximum temperature was 33.75°C whereas it was 33.11°C in the period 2007-2011 (Figure 1), that means it increased to almost 0.64°C. In contrary, the month January is the coldest and has shown the lowest temperature in the year. Temperature as low as 5ºC was recorded in January 2007 which was the lowest in the history of last 38 years in Bangladesh [11]. The maximum temperature from December to February shows the trend of cooling; while from April to October it exhibits the trend of strong warming in both periods**.** So, this climatic data indicate increase in both extreme cold and hot weather in the month of January and April.

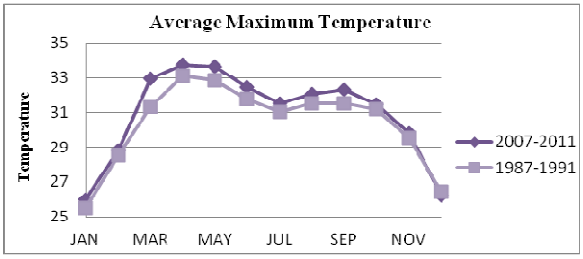

Figure 1. *Average Maximum Temperature*

3.2.1. Spatial Distribution of Temperature

Using the inverse distance weighted (IDW) interpolation technique spatial distribution maps of average value of annual maximum and minimum temperatures over Bangladesh has been developed. Figure 2 shows distribution of average annual maximum temperature. Average minimum temperature is presented in Figure 3.

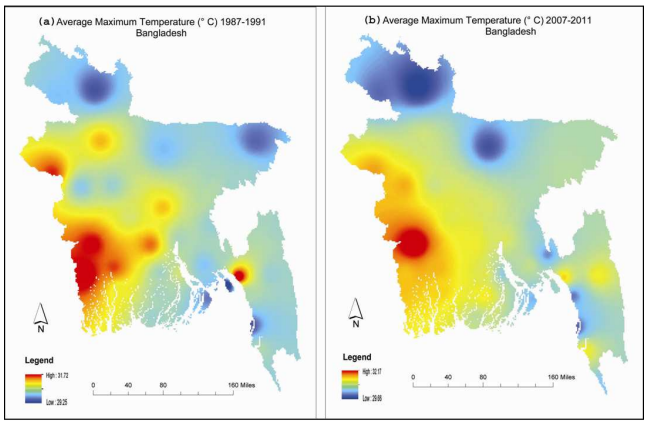

Figure 2. *Spatial maximum temperature variation: (a) for 1987-1991 and (b) for 2007-2011*

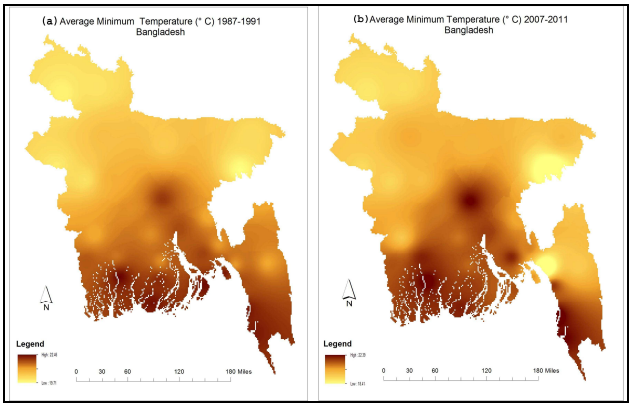

Figure 3. *Spatial minimum temperature variation: (a) for 1987-1991 and (b) for 2007-2011*

From the station wise average annual temperature, it is concluded that the hottest regions of Bangladesh in the period 1987-1992 were Sitakunda, Jessore, Khulna and Sathkhira where the temperature varies between 31°C to 31.75°C (Figure 2a). In contrast, in the period 2007-2011 temperature increases in the range between 31°C to 32.20°C in almost all stations especially Jessore, Isurddi, Khulna, Sathkhira, Sitakunda, Cox's bazar, Rangamati and Mongla (Figure 2b). The hottest region was found to span from Sitakunda to Mongla. In case of average maximum temperature, most of the regions are more than 30°C or more in Dinajpur, Rangpur, Mymenshing, Maijdee court, Hatiya, Sandwip and Kutubdia except Rangpur and Mymensingh districts. Southern parts of the country show the higher trend of daily maximum temperature than that of other parts of the country. On the other hand, from average minimum temperature data, the Sylhet region has found to be the coolest area. In both periods the coolest area of Bangladesh is Srimongal. The northern and central parts of the country have shown the trend of gradual cooler. The Chittagong Hill Tracts region shows mixed characteristics over these time periods. From the above analysis, we conclude that, the maximum temperature has been increasing over the years due to urbanization, industrialization, emission of GHGs and at the same time, the minimum temperature has also been decreasing.

3.3. Rainfall

It is another most important dominant element of the climate of Bangladesh. Rainfall pattern changes due to climate change although the exact degree of change is not possible yet to determine. The western depression of winter, the early summer thunderstorm and the summer rain are the main sources of rainfall in Bangladesh. The mean annual rainfall is about 2320 mm in Bangladesh, but there are some places with a mean annual rainfall of 6000 mm or more [12]. It clearly indicates that Bangladesh rightly qualifies to be a country of heavy rainfall. More than 70 percent of rainfall in Bangladesh comes during monsoon season (June-September) and remaining covers eight months from October to May [13]. The rainfall intensity also varies geographically, where "mean annual rainfall increases from about 1250 mm in the centre-west to over 5000 mm in the extreme north-east" [14]. From Table 1, the average annual rainfall of Bangladesh was 2586.53 mm (215.53 mm per month) in the period 1987-1991 whereas it decreased to 2435.82 mm (202.99 mm per month) in the period 2007-2011. To analysis annual rainfall in both periods it is found that, almost 150 mm rainfall decreased at the rate of 12.56 mm per year between the two periods but compared with the national average it has been increased. The difference in monthly rainfall between these two periods suggests that the annual rainfall pattern has changed with a high concentration of extreme rainfall in May to September. It increases the risk of natural hydrological hazards such as flood, erosion, and landslide. This data indicate that, the rainy season of Bangladesh covers four months (June to September) where most of the rainfall occurred (Figure 4). Table 1 indicates that in the period 2007-2011, a maximum rainfall 569.3 mm/month was observed in the month of July and in the period 1987-1991, the maximum rainfall was more than 12.8 mm in the same month. In the period 1987-1991, the average rainfall was higher in all months (except January and October) than in the period 2007-2011. That means heavier rainfall occurred all over the country within a short time period during the monsoon months and the latter period was characterized by increasing drought events. Table 1 shows that the average annual rainfall decreased annually at the rate of 0.63 mm.

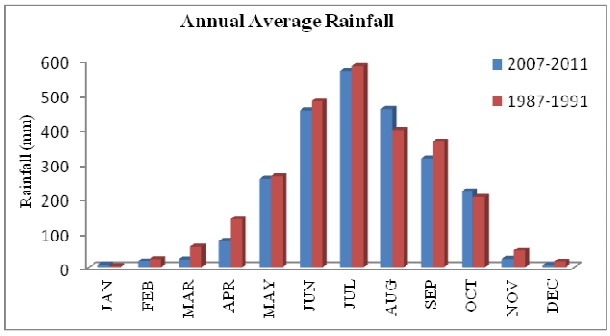

Figure 4*. Variation of annual average rainfall*

Future climate change projections show increased rainfall during monsoon (JJA) season and declining rainfall in months of winter (DJF) (Table 2). Though rainfall in monsoon season is projected to increase, the rainfall variability may increase significantly causing more intense rainfall and/or longer dry spells [15]. The rainfall increasing in Bangladesh during the summer monsoon is forecasted to be around 1-4% by the 2020s, and 2-7% by the 2050s [16] and in winter rainfall is likely to increase by 3.8 to 10.4% in the year 2030 and 2075 [17].

***Table 2**. Modeled change in temperature and rainfall [15]*

Year	Temperature changes (^{0}C) (Mean standard deviation)			Rainfall changes (^{0}C) (Mean standard deviation)		
	Annual	**DJF**	**JJA**	**Annual**	**DJF**	**JJA**
Baseline Average				2278	33.7	1343.7
2030	1.0 (0.11)	1.0 (0.18)	0.8 (0.16)	3.8 (2.30)	1.2 (12.56)	4.7 (3.17)
2050	1.4 (0.16)	1.6 (0.26)	1.1 (0.23)	5.6 (3.33)	1.7 (18.15)	6.8 (4.58)
2100	2.4 (0.28)	2.7 (0.46)	2.7 (0.40)	9.7 (5.80)	3.0 (31.60)	11.8 (7.97)

Note: DJF represents the months of December, January and February, usually the winter season. JJA stands for the months of June, July and August, the monsoon season**.**

3.3.1. Spatial Distribution of Rainfall

Using inverse distance weighted (IDW) interpolation technique spatial distribution maps of average annual rainfall all over Bangladesh have been generated. Figure 4(a) shows the distribution of average of annual rainfall in the periods 1987-1991 and 2007-2011. We see that there is a significant change in spatial distribution of rainfall between two periods. Figure 5a shows that North-East and South-East regions have the maximum long term rainfall in Bangladesh in the period 1987-91 but in the period 2007-2011 it is only in the North-East region especially in Sylhet region (Figure 5b). Interestingly, Noakhali district surprisingly gets low rainfall whereas the Chittagong and Comilla districts adjacent to it get high amount of rain.

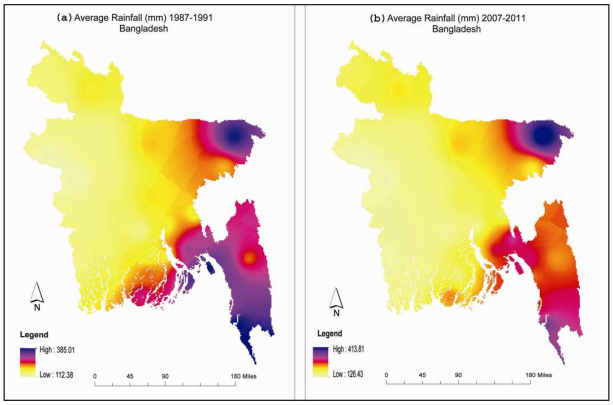

***Figure 5.** Spatial average rainfall variation: (a) for 1987-1991 and (b) for 2007-2011*

3.4. Relative Humidity

Relative humidity has shown to be decreased in a significant level in the period 1987-2011. The climate change impacts on the average annual relative humidity which decreases at 0.013 percent per year (Table 1). The average relative humidity was 80.36 percent during the period 1987-1991 but it decreased to 80.11 percent in the period 2007-2011 (Table 1). That means, the annual average relative humidity decreased about 0.17 percent during the period 1987-2011. The two data sets suggest that June to October have shown to portray the highest amount of humidity (about 80 percent) while the minimum relative humidity was recorded in the month of March in both periods. It proves that almost all of the month had less humidity than the previous period 1987-1991. It is also observed from the Table 1 that the normal relative humidity has decreased in all months except January, April and November. But this change is not remarkable.

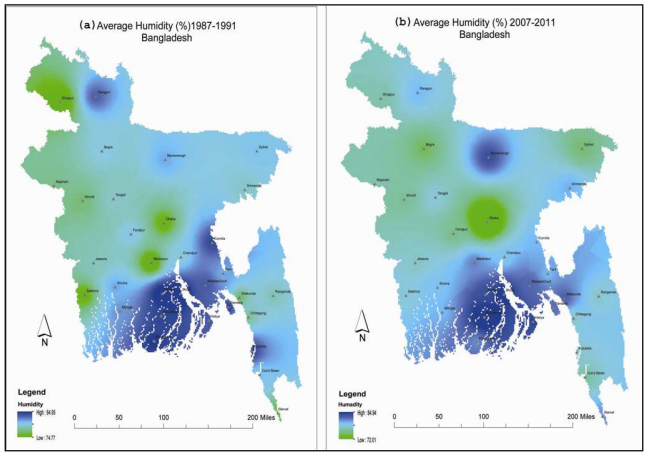

***Figure 6.** Spatial average humidity: (a) for 1987-1991 and (b) for 2007-2011.*

3.4.1. Spatial Distribution of Humidity

From the map of spatial distribution of humidity, it is observed that the maximum relative humidity was recorded in the district of Bhola, Barisal and Khepupara in the period 1987-1991 (Figure 6a), while the maximum relative humidity in the period 2007-2011 was recorded in the district of Patuakhali, Bhola, Hatiya , Barisal, Mymenshing and Sitakunda (Figure 6b). The southern and the north eastern parts of the country have a higher trend in relative humidity compared to the rest of the country. In the period 1987-1991, the western and central parts had the less humidity but in the period 2007-2011, the central part of the country experienced the less humidity. In comparison between two periods, almost 15 stations have shown increasing trend of annual humidity than the period 1987-1991.

3.5. Cloud Coverage

Clouds are important in the earth's climate system because it impacts on solar radiation, terrestrial radiation, and precipitation depending on cloud height, thickness, horizontal extent and variability, and the sizes of droplets [18]. Clouds affect surface temperature, and surface temperature can also affect cloud development. During the period 1987–1991, the average annual cloud coverage was estimated to be 2.14 whereas during the period 2007–2011, it decreased by about 0.69 (Table 2). Almost every month

(except January, august and September) the average cloud coverage decreased than previous period 1987-1991.

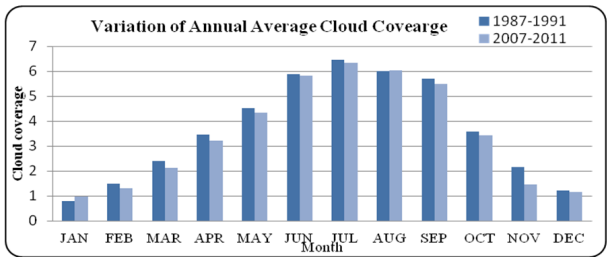

Figure 7. *Variation of annual average cloud coverage*

3.5. Impacts of Climate Change on Extreme Disasters

At present, Bangladesh is widely considered as one of the most vulnerable countries in the world regarding climate change, natural disaster and environmental degradation [19]. The fourth assessment report (2007) of the IPCC warns that extreme weather events and climate variability will increase the risks of natural disasters such as floods, cyclones, drought, sea level rise, coastal erosion, landslides etc and their impacts would be felt more severely in Bangladesh. It also suggests that Bangladesh might lose as much as one-third of its landmass due to the potential sea level rise, storm surges and anomalies in monsoon circulations. In terms of inherent natural calamities, Bangladesh is recognized one of the most vulnerable countries of the world which already facing the challenges of climate change. In recent times, natural hazards of Bangladesh are more frequent and intense compared to that occurred in last two or three decades ago. Now, it is globally accepted that this frequent climatic hazards are the result of the climate change. The floods of 1987, 1988, 1998, 2004 and 2007 and cyclones of 1991, 1997, 2007 and 2009 are treated as a result of the impact of climate change in Bangladesh. According to the IPCC third report (2001) and fourth assessment (2007) reports for Bangladesh, the projections show that by 2030, a 0.7°C temperature rise in monsoon season and a 1.3°C rise in the winter season might take place, on the other hand, sea level rise in Bangladesh would inundate about 18% of the country by 2100 [20].

3.6. Impacts of Climate Change on Flood

"When the Himalayas were covered in trees, Bangladesh suffered a major flood about twice a century; now it is once in every four years on average" [21]. It is the real present condition for the flooding of Bangladesh. Bangladesh is the part of world's most dynamic hydrological and the biggest active delta system where one fourth of the total area inundated annually on average and an extreme flood may inundate more than sixty percent of the total area. Floods will be more frequent due to temperature change and rainfall variation. Rise in temperature will accelerate the rate of melting of snow and glacier ice, increasing seasonal peak flows of Himalayan headwaters which in turn may lead to an increased frequency of flooding [22]. Elsewhere the erratic rainfall behaviors characterized by lesser number of rainy days but heavy precipitation events would become more frequent that severe flooding will happen more often, as it did in Dhaka in 2004 and 2007. Bangladesh went through six severe floods in the last 25 years causing 45 million people to be internally displaced [23]. It is found from this study that recently extreme flood events are increasing, although the total flood volume entering remains almost unchanged. Due to the impact of climate change especially for sea level rise and temperature increases, and erratic rainfall, the duration and frequency of flood also increase in Bangladesh. From figure 8, it is clearly seen that, the two big consecutive floods (1987 and 1988) considered as the most devastating flood disaster of Bangladesh which occurred only within 10 years and another extreme floods occurred in 2004 and 2007 which cannot be considered as usual climatic incident. Figure 8 shows year-wise flood affected area in Bangladesh. The most extreme floods are shown in red color and the extreme floods are shown in yellow color.

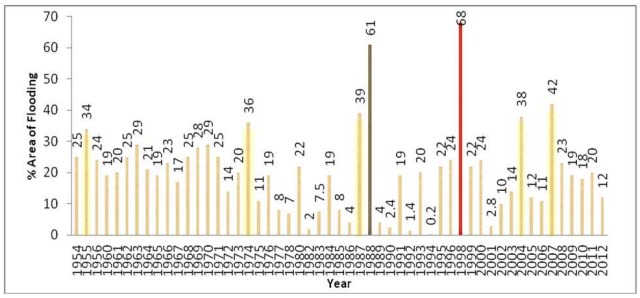

Figure 8. *Climate Change Impacts on the Trend of Historical Floods [24]*

Figures 8 provides a clear evidence that the extreme flood events have significantly increased and all five of the most extensive floods in the period 1954-2012 occurred after 1986 (1987, 1988, 1998, 2004, 2007) and it is also a striking feature that two record floods (1988 and 1998) occurred in this time that have a return period of 100 years or more but it occurred twice within a short span of time. That means the extent of big floods seems to have gradually increased. A number of elements such as land-use changes, (e.g. deforestation), loss of beels and swamp, [25], sea level rise and temperature increase, heavy precipitation events etc. is mainly responsible for the increased affected area during very big flood events. The effects of climate change on flooding are understood from the facts that about 18% of current lowly flooded areas will be susceptible to higher level of flooding, and about 12-16% of new areas will be at risk of flooding at various levels while in an average yearly, flood prone areas will increase from 25% to 39% [26].

3.7. Impact of Climate Change on Cyclone

In the context of human exposure for cyclone hazard, nearly 4,641,060 people are vulnerable for this hazard and Bangladesh ranked 6th out of 89 nations [27]. A study by UNDP [28] identified Bangladesh as the most vulnerable country in the world to tropical cyclones and it will become more frequent and severe in the future as a result of climate

change. It is predicted that global warming will cause an annual temperature rise of 0.4^0 C in Bangladesh [20] and almost every year cyclones hit the coastal regions of Bangladesh in pre-monsoon (April-May) or post-monsoon season (October-November) but at present its intensity and frequency is more than that of previous period. It is also predicted that, at present the frequency of cyclone is much more than previous period because of the rise of temperature. From this study, we see that the average mean maximum annual temperature increased about 0.64°C during the last 20 years. It is found that, during the period 1970-2013, one hundred thirty four (134) major and minor cyclones hit the coast of Bangladesh (Figure 9). Among them almost two-third (88) of them hit in the period 1992-2013 which is very alarming for our survival. This study showed that the average mean maximum annual temperature increases about 0.64°C from the period 1987-1991 and 2007-2011 and the average minimum temperature decreased slightly which almost decreased by 0.07°C (Table 1). This temperature increase is attributed to the increase in the intensity and frequency of cyclone.

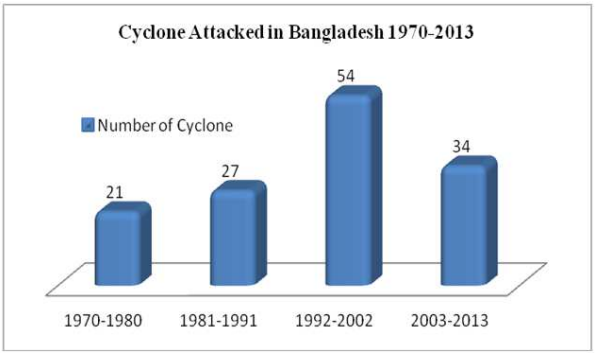

Figure 9. *Number of cyclone landfall in Bangladesh [29].*

From the impact of climate change, it is predicted that future tropical cyclones will become stronger more than present with larger peak of wind speeds and more heavy rainfall associated with ongoing increases of tropical sea surface temperatures [30]. It is also predicted that, cyclones are expected to have 3% to 12% faster wind speeds by the 2020s, rising to 4% to 20% faster by the 2050s in Bangladesh which is very alarming rate [16].

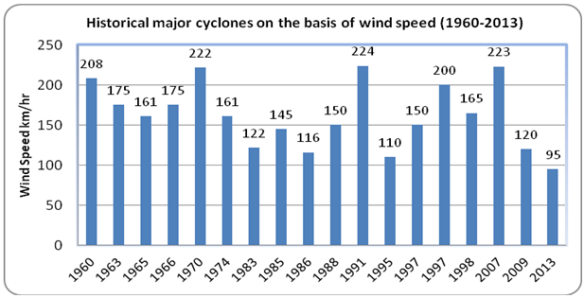

Figure 10. *Historical Major Cyclones (1960-2013). [7] and [31]*

In Bangladesh, cyclone intensity analysis shows that the frequency and the intensity of cyclone (more than 200 km/hour) have an increasing trend in last two or three decades (Figure 10). Cyclones currently occur at a rate of 1.3 per year with speeds more than 275 km per hour [32]. It is projected that including the present vulnerable people another 7 million coastal people will confront cyclones by 2050 because of the changing climate [6]. Most destructive cyclone of Bangladesh was 224 km/h in 1970 that killed almost 300,000 people and after twenty years later in 1991 the 225 km/h cyclone occurred that killed about 140,000 people. But after 1991 to till now a lot of super cyclone hit in Bangladesh with wind speed more than 200 km/h. Among them cyclones in 1997 and 2007 were the most notable ones (Figure 10). After that two additional cyclones hit coastal area of Bangladesh namely Cyclone *Aila in 2009* and Cyclone *Mohasen* in 2013. That means the intensity of cyclone in Bay of Bengal has increasing trend especially from the last two or three decades due to rise in ocean temperature. It is found that warmer ocean temperatures increase the frequency and intensity of these cyclone activities [33] and it is also observed that the temperature of Bangladesh has increasing trend and its side effect the extreme natural events are increasing day by day.

3.8. Others Disasters

Others remarkable disasters like river bank erosion, drought, and extreme temperature events in winter seasons are increasing from the last two or three decades due to the impact of climate change. Higher volumes of water are flowing down the rivers due to the climate related changes such as increased rainfall and summer glacier melt in the Himalayan Mountain may also increase the erosion of land beside Bangladesh's rivers. River bank erosion includes channel shifting, the creation of new channels during floods, bank slumping due to undercutting and local scour from turbulence caused by obstruction [26]. In fact a recent study by the Centre for Environment and Geographical Information Systems (CEGIS) found that between 1943 and 2008 Bangladesh added 2970 km² in new char-land through deposition, while it lost 1180 km² through erosion leading at a net gain of 1800 km² of land. On the other hand, every year Bangladesh experiences a dry period from November to May, when rainfall is normally low. During this period about 2.7 million hectares of land in Bangladesh are vulnerable to annual drought and there is about 10% probability that 41-50% of the country experiences drought in every year [16]. Recently in every year, a huge number of people died for climate change induced extreme temperature in Bangladesh. In the last 10 years severe cold waves have become common scenario in Bangladesh [34], and in January 2007, temperatures as low as 5ºC were recorded in Bangladesh.

For the period 2000-2010, about 1335 people died for extreme temperature in Bangladesh [29]. It is another important climate change induced natural disaster of Bangladesh. So, besides increasing the frequency and intensity of cyclone and flood, we are affected with these disasters more than previous year because of climate change.

4. Conclusions

Climate change has some clearly established impacts on intensity and frequency of natural disaster and poses a great threat to human survival around the world. It is worldwide recognized that, Bangladesh is one of the top most nations vulnerable to climate change.

From this study it is found that, compare to the past period 1987-1991 climatic variables, the present climate trends and variability in Bangladesh can be characterized by increasing maximum air temperatures, decreasing minimum temperature, rainfall, humidity and cloud coverage and there is an increasing trend in the intensity and frequency of extreme events in Bangladesh. Analysis of monthly average maximum temperature showed increasing trend for all months throughout the year which increased almost 0.03°C annually and minimum temperature decreased at the rate of 0.003°C per year for the last 20 years. At the same time the annual rainfall and relative humidity also decreased at the rate of 1.15 mm and 0.02 % respectively. These climatic changes had significant impact on extreme natural disasters of Bangladesh. It is also found that impacts of climate change have increased the natural hazard events and their severity in the last two or three decades which is alarming for our survival because extreme events have negative impact on water, agriculture and food security, forestry, health, and tourism. As temperature, rainfall and humidity patterns are of great importance for our agro-based economy but these changes will threaten the significant achievement of Bangladesh. This study concludes that climate change has occurred significantly and its impact on severity and frequency of natural disasters has reached an alarming rate in Bangladesh.

References

[1] Asaduzzaman, M, Ringler, C, Thurlow, J & Alam, S 2010, 'Investing in Crop Agriculture in Bangladesh for Higher Growth and Productivity, and Adaptation to Climate Change', Presented at the Bangladesh Food Security Investment Forum, 26–27 May 2010, Dhaka.

[2] Yu, W, Alam, M, Hassan, A, Khan, AS, Ruane, AC, Rosenzweig, C, Major, DC & Thurlow, J. 2010. Climate change risk and food security in Bangladesh, EarthScan, London.

[3] IPCC (Intergovernmental Panel on Climate Change). 2007. Fourth Assessment Report (AR4), Climate Change, Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

[4] McCarthy JJ, Canziani OF, Leary NA, Dokken DJ, White KS, Eds. Climate Change 2001: Impacts, Adaptation. and Vulnerability, Inter Governmental Panel on Climate Change (IPCC), Work Group II Input to the Third Assessment Report, Cambridge University. Press, Cambridge.

[5] Harmeling, S ; Eckstein ,D. 2012. Global Climate Index 2013. Who suffers most from extreme weather events? Weather-related loss events in 2011 and 1992 to 2011. Kaiserstr 201, Bonn, Germanwatch e.v. Available at: www.germanwatch.org/en/cri.

[6] World Bank (2001). Bangladesh: Climate change and sustainable development. World Bank Office, Dhaka

[7] BMD (Bangladesh Meteorological Department).Unpublished raw data, Dhaka.

[8] BARC (Bangladesh Agricultural Research Council). Available at: http://www.barc.gov.bd/lt_climate.php

[9] BWDB (Bangladesh Water Development Board). Unpublished raw data, Dhaka.

[10] Ahmad, Q.K., Warrick, R.A., Ericksen, N.J. and Mirza, M.M.Q. 1996. The implications for climate change for Bangladesh: A synthesis, In R.A. Warrick and Q.K. Ahmad (eds.), The implications of climate and sea-level change for Bangladesh, Kluwer Academic Publishers, Dordrecht, The Netherlands.

[11] Reid, S., Smit, B., Caldwell, W. and Belliveau, S. (2007), "Vulnerability and adaptation to climate risks in Ontario agriculture", Mitigation and Adaptation Strategies for Global Change, Vol. 12 No. 4.

[12] Hossain, M., Islam, A.T.M.A. and Saha, S.K. 1987. Floods in Bangladesh-an analysis of their nature and causes In: Floods in Bangladesh Recurrent disaster and people's survival. Universities Research Centre, Dhaka, Bangladesh.

[13] Khan, H. R. 1991. ''Impact of flood control and drainage projects on agricultural production in Bangladesh'', paper presented at a seminar jointly organized by the Institution of Engineers, Bangladesh, and American Society of Civil Engineers, Bangladesh, Dhaka.

[14] Brammer, H.1990. "Floods in Bangladesh: Flood mitigation and Environmental aspects", The Geographical Journal, 156(2), Jul.

[15] ADPC, 2007. Climate variability and change: adaptation to drought in Bangladesh. FAO, Rome, Italy

[16] Tanner T.M., Hassan A, Islam KMN, Conway, D, Mechler R, Ahmed AU, and Alam, M. 2007. ORCHID: Piloting Climate Risk Screening in DFID Bangladesh. Detailed Research Report. Institute of Development Studies, University of Sussex, UK.

[17] Roy, K., Rahman, M., and Kumar,U. 2009. Future Climate Change and Moisture Stress: Impact on Crop Agriculture in South-Western Bangladesh. Climate Change and Development Perspective, Unnayan Onneshan. Volume 1, Issue 1. Dhaka, Bangladesh.

[18] Warren, S.G. and Eastman, R.M. 2007. A Survey of Changes in Cloud Cover and Cloud Types over Land from Surface Observations, 1971–96. Journal of Climate, volume-20. doi: 10.1175/JCLI4031.1.

[19] Panda, A. 2011. "Climate induced migration from Bangladesh to India: Issues and challenges", UNU-E

[20] Islam, M.R., 2004. Living in the coast: Problems, opportunities and challenges. Working Paper WP011, Dhaka. 2004, Programme Development Office (PDO) and Integrated Coastal Zone Management Plan (ICZMP).

[21] UNEP (United Nations Environment Programme). 1992. Our Planet 4(2).

[22] Douglas. I. 2009.Climate change, flooding and food security in south Asia. Food Sec. (2009) 1:127–136.DOI 10.1007/s12571-009-0015-1.

[23] International Organization for Migration, 2010. Assessing the Evidence: Environment, Climate Change and Migration in Bangladesh. Regional Office for South Asia: Dhaka.

[24] FFWC, 2012, "Annual Flood Report", Flood Forecasting and Warning Centre (FFWC), Bangladesh Water Development Board (BWDB), Dhaka, Bangladesh.

[25] Hofer, T; Messerli, B. 2006. Floods in History, dynamics and rethinking the role of the Himalayas.United Nations University Prees, New York.

[26] Ahmed, A.U. 2006. Bangladesh Climate Change Impacts and Vulnerability: A Synthesis. Dhaka : Climate Change Cell, Bangladesh Department of Environment.

[27] IDDRI (Institute for Sustainable Development and International Relations) / International Organization for Migration (IOM), 2012. The State of Environmental Migration 2011. France.

[28] UNDP, 2004: A Global Report, Reducing Disaster Risk, A Challenge for Development.

[29] EM-DAT: The OFDA/CRED International Disaster Database – www.emdat.be, Université Catholique de Louvain, Brussels (Belgium). Available at: http://www.emdat.be/disaster-list.

[30] Alley et al, 2007. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change: Summary for Policymakers. IPCC Secretariat: Geneva, Switzerland.

[31] Shelter Preparatory Study (CPSP). 1998. Stage I: Feasibility Study, Draft Final Report; Supp. Vol. 3, Community Development Studies, Part A, Supp. Vol. 8; Environmental Analysis.

[32] Chowdhury, A. 2002. Disasters: Issues and Responses. In: Bangladesh Environment: Facing the 21st Century. (2nd ed.) Ed. Gain, P. Dhaka : Society for Environment and Human Development (SEHD).

[33] Williams, M. 2002. Climate Change Information Kit. The United Nations Environment Programme and the Climate Change Secretariat (UNFCCC) and sponsored by UNEP, the UN Development Programme, the UN Department of Economic and Social Affairs, the UN Institute for Training and Research, the World Meteorological Organization, the World Health Organization, and the UNFCCC : Geneva, Switzerland.

[34] Roach, R. 2005. Dried up, drowned out: Voices from the developing world on a changing climate. Teddington, Middlesex, UK : Tearfund.