

Trend analysis of Climate Change in Chittagong Station in Bangladesh

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ABSTRACT. The amount of rainfall received over an area is an important factor in assessing availability of water to meet various demands for agriculture, industry, irrigation, generation of hydroelectricity and other human activities. Over the study period of recent 30 years, trend values of monsoon average rainfall in Chittagong have increased. This paper has measured the correlation coefficients between rainfall and time for Chittagong, where correlation coefficient for Chittagong is positive. In order to check the strength of linear relationship between rainfall and time, P-value has been measured. Due to various factors of Chittagong region of Bangladesh, there is a growing need to study the rainfall, temperature and humidity pattern. This study was checked annual average rainfall of 30 years, temperature of 60 years and humidity of 28 years for this region. It is hoped that this research may be of help to the concerned organizations and experts working on increasing climate variation in Chittagong.

1. INTRODUCTION

Rainfall is one of the most important factors of Bangladesh where the economy strongly based on agriculture. About 80% people of Bangladesh live in village and directly or indirectly depend on agriculture. Bangladesh is blessed with the largest unbroken sea shore, the largest mangrove forest, rich mountain ranges, vast green scenic serene, ample natural resources, and huge manpower; however despite huge potential, the country is still on her struggle to advance from an unfavorable economic state. Due to its geographic location and dense population, the country is considered as one of the most vulnerable countries of the world. The country has very least capacity to address the devastating impacts. According to the recent IPCC report (IPCC 2007), Bangladesh will experience 5% to 6% increase of rainfall by 2030. The erratic rainfall and their associated extreme events may affect ecosystems, productivity of land, agriculture, food security, water availability and quality, health and livelihood of the common people of Bangladesh.

Now it is evident from scientific study that our mother climate has undergone an abnormal human induced change. Various climatic parameters such as rainfall, temperature, humidity, sunshine hour etc. of various regions of the world have shown significant trends. Humidity (atmospheric moisture) is an important component of environment. Atmospheric moisture level has significant influence on plant growth and development. Both very low and high relative humidity may cause some physical discomfort mainly indoor diseases as the relative humidity of the air directly affects temperature. Thus, a better understanding of climate has important implications for the economy and society of Bangladesh.

2. CLIMATE OF BANGLADESH

Four distinct seasons can be recognized in Bangladesh from the climatic point of view: (1) dry winter season from December to February, (2) pre-monsoon hot summer season from March to May, (3) rainy monsoon season from June to September and (4) post-monsoon autumn season which lasts from October to November [1] Rainfall in Bangladesh mostly occurs in monsoon

period, caused by the weak tropical depressions that are brought from the Bay of Bengal into Bangladesh by the wet monsoon winds. More than 75% rainfall occurs in the monsoon period. Average temperature of the country ranges from 17 to 20.6°C during winter and 26.9 to 31.1°C during summer. Average relative humidity for the whole year ranges from 70.5% to 78.1% in Bangladesh [2].

The pre-monsoon hot season comes with high temperature and occurrence of thunderstorms. April is the hottest month in the country when mean temperature ranges from 28°C in the east and south to 32°C in the west-central part of the country. After April, increasing cloud-cover dampens temperature. Wind direction is variable in this season, especially during its early part. Rainfall accounts for 10 to 25 percent of the annual total, which is caused by thunderstorms. Winter is very short goes at peak in early January. Average temperature in January varies from 17°C in the northwest and northeastern parts of the country to 20°C-21°C in the coastal areas. Minimum temperature in the extreme northwest in late December and early January reaches 5°C to 6°C. The average temperature of the country ranges from 7.2°C to 12.8°C during winter and 23.9 to 31.1°C during summer. Generally, annual average rainfall varies from 1500 mm to 2500 mm but near the eastern border this rises to 3750 mm. During the hot season, there are rainstorms, some thunders, and during the main rainy season, the rain is frequent and heavy. Heavy rainfall is usually associated with violent tropical cyclones that develop over the Bay of Bengal.

3. OBJECTIVES

The main objectives of the study are:

- Regression analysis of rainfall data
- Determine the correlation coefficient for Chittagong station
- Testing the significance of correlation coefficient
- Determine the strength of linear relationship between rainfall and time
- Focus the impacts of rainfall variation
- Trend analysis of temperature data
- Coefficient of variation analysis of humidity data

4. LITERATURE REVIEW

Both home and abroad, a number of studies have been conducted to examine the patterns and trend of rainfall based on daily, monthly, seasonal and yearly rainfall data. In this section, only those studies that have dealt with the patterns trend of rainfall are reviewed briefly. However, other relevant studies are referred to at appropriate places in this dissertation.

Gregory (1956) has examined the Regional variations in the trend of annual rainfall over the British Isles for the period 1881-1950 and he has found that annual rainfall values have fluctuated considerably over the years and also that these fluctuations varied from one part of Britain to another. He has noted the major implications of the regional variations in annual rainfall trends. [3]

Panabokke and Walgame (1974) have studied the application of rainfall confidence limits to crop water requirements in dry zone agriculture in Srilanka". They have observed that in many areas of the seasonally arid tropics, crops must be planted early and the date of the start of growing season should coincide with the first heavy rainfall. [4]

Parthasarathy and Dhar (1974) have studied the secular variations of regional rainfall over India for the period 1901-1960. They have shown that the yearly rainfall data for western part in Indian Peninsula to central parts of the country follow a positive trend. The yearly rainfall data for some sub-divisions, namely Punjab, Himachal Pradesh and Assam follow an increasing trend. However, south Assam is the only sub-division where rainfall data show a negative trend. [5]

Parathasarathy et al. (1987) and Divya and Mehritra (1995) reported mean annual temperature of Bangladesh has increased during the period of 1895-1980 at 0.31°C over the past two decades.[6]

Benoit (1977) has studied the start of growing season rainfall in northern Nigeria for the years 1951-1975. He has found that the date of start of the growing season is occurred when the accumulated rainfall exceeds one half of potential evapotranspiration for the remainder of growing season, provided that no dry spell longer than five days occur immediately after this date. The mean start of the growing season of locations in northern Nigeria is related to latitude, where the growing season starts later than that at southern locations. [7]

Chowdhury and Debsharma (1992) and Mia (2003) pointed out that temperature has been changed by using historical data of some selected meteorological station.[8],[19]

Stern et al. (1981) have examined the start of the rains in West Africa for the period 1934-1965. In this study of the rains is defined as the first occurrence of a specified amount of rain within two successive days. They have found that the probability of rains depends only upon whether the previous day was wet or not. The earliest possible start of rains is defined by the probability of dry spells, when the relationship between start and latitude is not linear. This definition is used to indicate the showing periods, when safe planting is required.[9]

Stern et al. (1982) have analyzed the daily rainfall data for Kano, Sholapur and Hyderabad, India for the period 1916-1975 with a view to provide agronomically useful results by a direct method and a modeling approach. Through the direct method, they have obtained the probability of an event like start, end of the rains etc. directly from the relative frequency of rainfall occurrences.[10]

Roy et al. (1987) have studied the trends of regional variations and periodicities of annual rainfall in Bangladesh for 32 years between 1947 and 1979 at 30 meteorological stations and they have shown the yearly rainfall amounts for most of the stations follow a normal distribution. Annual rainfall data for Rajshahi, Ishwardi, Pabna and Khulna stations have shown positives trends while for comilla stations a negative trend has been found. [11]

Nguyen and Pandey (1994) proposed a mathematical model to describe the probability distributions of temporal rainfall using data from seven rain gauge stations. The study considers multifractal multiplicative cascade model. The model provides adequate estimates of the hourly rainfall distribution and hence can be used in locations where these short-duration Rainfall data are not available. [12]

A number of studies have been carried out on rainfall patterns (Ahmed and Karmakar, 1993; Hussain and Sultana, 1996; Kripalini et al., 1996; Rahman et al., 1997; Ahmed and Kim, 2003; Shahid et al., 2005; Islam and Uyeda, 2008; Shahid, 2008), only very few works have been found on rainfall trends and extremes in Bangladesh.

Rahman et al. (1997) used trend analysis to study the changes in monsoon rainfall of Bangladesh and found no significant change. [13]

Ahmed (1989) estimated the probabilistic rainfall extremes in Bangladesh during the pre-monsoon season. [14]

Karmakar and Khatun (1995) repeated a similar study on rainfall extremes during the southwest monsoon season. However, both the studies were focused only on the maximum rainfall events for a limited period. [15]

Karmakar and Shrestha (2000) using the 1961-1990 data for Bangladesh projected that annual mean maximum temperature will increase to 0.4°C and 0.73°C by the year of 2050 and 2100 respectively.[16]

Suhaila Jamaludin and Abdul Aziz Jemain (2007) have studied the fitting the statistical distributions to the daily rainfall amount in Peninsular Malaysia. Daily rainfall data have been classified according to four rain type's sequence of wet days. [17]

Shamsuddin Shahid (2009) has analyzed Rainfall variability and the trends of wet and dry periods in Bangladesh over the time period 1958–2007 has been assessed using rainfall data recorded at 17 stations distributed over the country. The result shows a significant increase in the average annual and pre-monsoon rainfall of Bangladesh. The number of wet months is found to increase and the dry months to decrease in most parts of the country. Seasonal analysis of wet and dry months shows a significant decrease of dry months in monsoon and pre-monsoon.[18]

5. MATERIALS AND METHODOLOGY

The daily rainfall data for the period 1979-2008 collected by the Department of Meteorology, Government of People's Republic of Bangladesh have been employed in this study. In this study, the period between the months of May to October has been considered as the rainy season or monsoon period. The whole Bangladesh has been divided into four zones named Chittagong, Dhaka, Rajshahi and Sylhet according to the amount of annual rainfall. Maximum and minimum daily temperature data of last sixty years (1948-2007) has been collected from Chittagong station of BMD located all over the Bangladesh have been used in this study. The whole Bangladesh has been divided into 34 stations. The annual average humidity of Bangladesh has been studied on the basis of available data of 28 years (1981-2008). The annual average humidity data of Bangladesh divided into 30 meteorological stations. One important meteorological station, Chittagong has been selected from these zones to analysis the rainfall, temperature and humidity data.

Linear regression model

The linear regression line was fitted using the most common method of least squares. This method calculates the best fitting line for the observed data by minimizing the sum of the squares of the vertical deviations from each data point to the line. If a point lies exactly on the straight line then the algebraic sum of the residuals is zero. Residuals are defined as the difference between an observation at a point in time and the value read from the trend line at that point in time. A point that lies far from the line has a large residual value and is known as an outlier or, an extreme value.

The equation of a linear regression line is given as

$$y = a + bx$$

where, y is the observation on the dependent variable

x is the observation on the independent variable

'a' is the intercept of the line on the vertical axis and 'b' is the slope of the line.

The estimate of intercept 'a' and the regression coefficient 'b' by the least square method

$$\begin{aligned} \text{i.e.} \quad \hat{a} &= \bar{y} - \hat{b}\bar{x} \\ \text{and} \quad \hat{b} &= \frac{\sum (x - \bar{x})(y - \bar{y})}{\sum (x - \bar{x})^2} \end{aligned}$$

Coefficient of determination, $R^2 = (\text{SS due to Regression}) / (\text{Total SS})$

$$= \frac{\sum (\hat{Y}_i - \bar{Y})^2}{\sum (Y_i - \bar{Y})^2}$$

In order to fit regression lines of the in rainy season monthly average Rainfall (dependent variables) against time (independent variable) in years were plotted. Linear regression lines were then fitted to determine the trends of rainfall. The drawing of the diagrams and the fitting of the regression lines were done in Microsoft Excel.

Trend

By secular trend or simply trend we mean the general tendency of the data to increase or decrease during a long period of time. Temperature, rainfall and agriculture production data are made over time and therefore are referred to as time series data, which is defined as a sequence of observations that varies over time. Since the trend variation occurs over a substantial extended period of time, the stations 30 years of available data were considered suitable for the trend analysis. Trend is determined by the relationship between the two variables (rainfall and time).

Correlation coefficient

The correlation coefficient determines the strength of linear relationship between two variables. It always takes a value between -1 and $+1$, with 1 or -1 indicating a perfect correlation (all points would lie along a straight line in this case and having a residual of zero). A correlation coefficient close to or equal to zero indicates no relationship between the variables. A positive correlation coefficient indicates a positive (upward) relationship and a negative correlation coefficient indicates a negative (downward) relationship between the variables. The correlation coefficients between rainfall and time were calculated as follows.

Given the pairs of values $(x_1, y_1), (x_2, y_2), \dots, (x_n, y_n)$, the formula for computing the correlation coefficient is given by

$$r = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum (x_i - \bar{x})^2 \sum (y_i - \bar{y})^2}}$$

Testing significance of the correlation coefficient

In testing the significance of the correlation coefficient, the following null (H_0) and alternative (H_1) hypothesis were considered.

Hypothesis:

$$H_0: \rho = 0$$

$$H_1: \rho \neq 0$$

where, ρ is the population correlation coefficient.

The appropriate test statistics for testing the above hypothesis is

$$t = \frac{r\sqrt{(n-2)}}{\sqrt{(1-r^2)}}, \quad \text{d.f.} = n-2$$

The P-values were then calculated in the following manner.

$$P\text{-value} = 2P \{t > \text{Observed value of the test statistic}\}$$

Skewness, Kurtosis and statistic to measure change in kurtosis:

Skewness is a measure of the asymmetry of the probability distribution of a real-valued random variable about its mean. The skewness value can be positive or negative, or even undefined.

Kurtosis is any measure of the "peakedness" of the probability distribution of a real-valued random variable.^[1] In a similar way to the concept of skewness, *kurtosis* is a descriptor of the shape of a probability distribution and, just as for skewness, there are different ways of quantifying it for a theoretical distribution and corresponding ways of estimating it from a sample from a population.

We know the departure of

$$\sqrt{\beta_1} = \frac{(3rdcentralmoment)^2}{(2ndcentralmoment)^3} = \frac{\mu_3^2}{\mu_2^3}$$

From the normal value of zero is an indication of skewness in the frequency function of the sampled population, while departure is

$$\beta_2 = \frac{(4thcentralmoment)}{(2ndcentralmoment)^2} = \frac{\mu_4}{\mu_2^2}$$

from the normal value of 3 is an indication of kurtosis.

R.C. Geary (1935,1936) has suggested an alternative statistic which may be used for detecting change in kurtosis, particularly when sample contains less than 50 observations, the statistic is,

$$a = \frac{\text{Mean Deviation}}{\text{Standard Deviation}} = \frac{\frac{1}{n} \sum_{i=1}^n |x_i - \bar{x}|}{\sqrt{\frac{1}{n} \sum_{i=1}^n (x_i - \bar{x})^2}}$$

Coefficient of variation:

In probability theory and statistics, the **coefficient of variation (CV)**, also known as **relative standard deviation (RSD)**, is a standardized measure of dispersion of a probability distribution or frequency distribution. It is often expressed as a percentage, and is defined as the ratio of the standard deviation σ to the mean μ (or its absolute value, $|\mu|$).

The coefficient of variation (CV) is defined as the ratio of the standard deviation σ to the mean μ .

$$c_v = \frac{\sigma}{\mu}$$

It shows the extent of variability in relation to the mean of the population.

6. FINDINGS AND ANALYSIS

To observe that the trend of monsoon average Rainfall for Chittagong Station and trend value have been calculated by using least square method, the findings are presented in Table 1. Also trend values are plotted accordingly in Figure1.

Table 1: Computation of trend values of monsoon average rainfall of Chittagong.

Year (x)	Y=Average Rainfall(mm)	$t = \frac{x - \frac{1}{2}(1993+1994)}{\frac{1}{2}(Interval)}$	Trend values $\hat{Y} = \hat{a} + \hat{b}t$
1979	452.67	-29	404.10
1980	467.67	-27	405.79
1981	340.50	-25	407.47
1982	411.33	-23	409.15
1983	608.67	-21	410.84
1984	408.00	-19	412.52
1985	453.00	-17	414.21
1986	423.50	-15	415.89
1987	467.83	-13	417.58
1988	465.33	-11	419.26
1989	393.67	-9	420.95
1990	400.00	-7	422.63
1991	492.00	-5	424.32
1992	333.25	-3	426.00
1993	489.18	-1	427.69
1994	294.50	1	429.37
1995	340.00	3	431.06
1996	411.50	5	432.74
1997	462.00	7	434.43
1998	553.15	9	436.11
1999	514.25	11	437.80
2000	557.75	13	439.48
2001	352.18	15	441.17
2002	411.50	17	442.85
2003	413.75	19	444.54
2004	458.75	21	446.22
2005	352.75	23	447.91
2006	384.75	25	449.59
2007	647.00	27	451.27
2008	487.18	29	452.96

The estimated trend in Table 1 and graphical representation in Fig 1 of this study reflects that the monsoon average rainfall in Chittagong increasing over the time period. The simple regression coefficient indicates that on an average the rainfall in Chittagong is increasing 0.8424 ($b=0.824$) per year.

The trend for Chittagong is increasing which indicates there is a positive relationship between time and rainfall. Correlation coefficient for rainfall and time in Chittagong is 0.091. The P-Values for Chittagong station is 0.632. This indicates that the correlation coefficient is large.

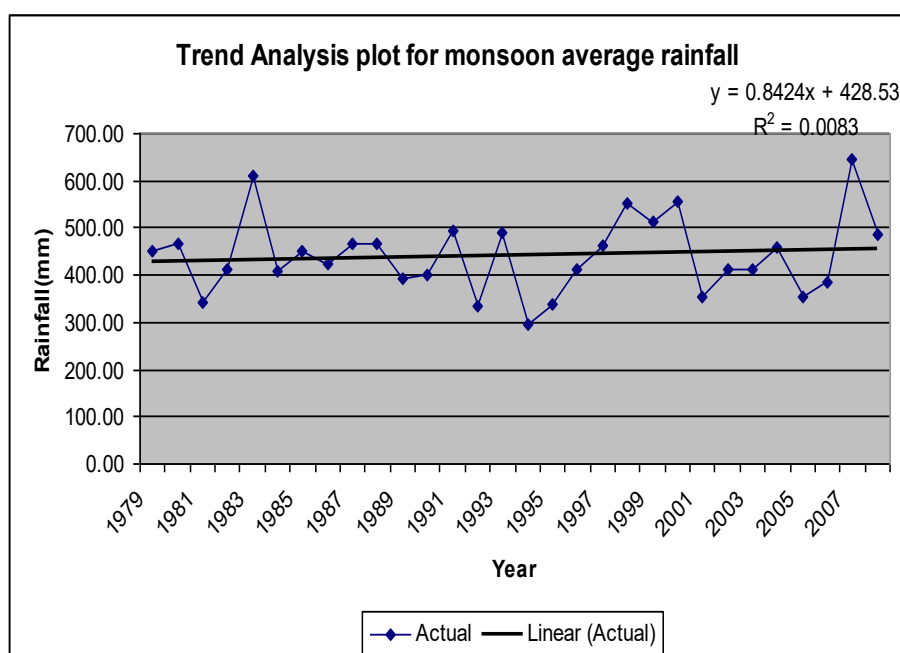


Fig 1: Trend Analysis Plot for monsoon average rainfall of Chittagong during period last 30 years (1979-2008).

Figure 1 shows that the trend of rainfall for Chittagong is increasing which indicates there is a positive linear relationship between rainfall and time. The R^2 value of about 0.0083 means that only 0.83% variation in rainfall is explained by time.

The correlation coefficients for four stations were calculated using the formula. The results are shown in Table 2

Table 2 Correlation coefficients for rainfall and time.

Station	Correlation Coefficients(r)
Chittagong	0.091

Table 2 shows that the positive relationship between rainfall and time at Chittagong station and the relationship between rainfall and time is weak.

P-value:

The P-values for Chittagong station which were used to determine the strength of linear relationship between the rainfall and time and thus establishing trend. The significance of the trend was tested at 5% level of significance. A trend exists if the P value is less than 0.05. P-values greater than 0.05 shows that trend is not significant.

Table 3 Test statistic and p-value of Chittagong station

Test statistic and P-value	Chittagong Station
Observed values of t	0.484
Degrees of freedom	28
P value	0.632

Table-3 shows that the P-values are large for Chittagong station and therefore the null hypothesis is not rejected. This implies that the correlation coefficient for rainfall is statistically insignificant.

Temperature:

Trends of daily maximum, minimum and mean temperature have been analyzed for Chittagong station of BMD. A summary of the trend analysis is presented in Table 4. In this table, latitude, longitude and altitude also have shown in this table. Available years of data and beginning year of each data set are also presented for each station.

Table 4: Trends ($^{\circ}\text{C}$ per 100 year) and R^2 of daily maximum and minimum temperature changes for Chittagong station

Lat.	Lon.	Alt	Start year	No. of years	Maximum Trend	R^2	Minimum Trend	R^2	Mean Trend	R^2
22.35	91.82	33.2	1949	59	2.24	0.53	0.9	0.15	1.58	0.41

Humidity:

Table 5: Skewness, kurtosis and coefficient of variation of average annual humidity for Chittagong

Station	Min ($^{\circ}\text{F}$)	Max ($^{\circ}\text{F}$)	Mean (%)	Mean Deviation (MD)	Std. Deviation (SD)	Skewness ($\sqrt{\beta_1}$)	Kurtosis (β_2)	CV (%)	$a=\text{MD} \div \text{SD}$
Chittagong	73	80	78.04	1.181	1.575	-1.227	2.410	2.018	0.749

Chittagong is recorded the moderate average humidity of Bangladesh. The standard deviation of annual average humidity is 1.575. The coefficient of variation is 2.018.

7. FACTORS INFLUENCING CLIMATE AND IMPACTS OF CLIMATE CHANGE

Liability Factors for climate change:

- **Climate change:** The strong increasing trend of pre-monsoon heavy rainfall days as well as rainfall amounts are observed in Chittagong station situated in southeast hill region of Bangladesh. The region experienced a number of landslides in the recent years. Significant increase of heavy rainfall events may trigger more landslides in the region in future. The climate determines the amount, intensity and distribution of rainfall which have direct influence on the effective rainfall. Reason behind increasing rainfall in Chittagong region is climate change.

- **Global warming:** Global warming brings more rainfall. Solar radiation is the primary driver of the water and energy cycles on Earth. About half of the total incoming solar (or shortwave) radiation at the top of the atmosphere is absorbed by Earth's surface, and the surface heats up. In an effort to cool itself, the surface emits terrestrial (or long wave) radiation. The net long wave loss from the surface, however, does not entirely compensate for the solar gain, and thus when the surface averaged globally and over the course of a year has a net radiative energy gain. To maintain total energy balance, there is a transfer of non-radiative energy from the surface to the troposphere. This non-radiative energy transfer takes primarily the form of latent and sensible heat fluxes, with the latent heat flux being about 5 times larger than the sensible heat flux in the global, annual mean. The latent heat flux from the surface to the troposphere is associated mainly with evaporation of surface water. When this water condenses in the troposphere to form clouds and eventually precipitation, the troposphere heats up and then radiates this energy gain out to space. The additional loss of radiative energy from the troposphere is approximately balanced by an additional gain of energy from enhanced latent heating associated with greater precipitation. In other words, global warming brings more rainfall to satisfy the requirement of tropospheric energy balance. An important consideration is that the increasing loss of long wave energy from the troposphere with global warming is partially offset by a decreasing efficiency of long wave energy loss with higher atmospheric carbon dioxide (CO_2) levels. The result of this CO_2 -induced reduction in long wave efficiency (or emissivity) is that a smaller increase in latent heating and thus rainfall increases. [20]

Impacts of climate change

- **Agriculture:** Agriculture plays an important role in the economy of Bangladesh which is very sensitive to rainfall. Increasing annual and pre-monsoon rainfalls and decreasing number of dry days may help to increase soil moisture contents as well as crop productivity in some parts of Bangladesh. Increases of rainfall and rainy days during pre-monsoon irrigation period can also reduce the pressure on groundwater for irrigation in Bangladesh. On the other hand, increasing heavy rainfall events during rice harvesting period in the month of May can cause the crop land flooded and major agricultural losses.

In winter season (November-February), the main crops of Bangladesh are Boro (rice), wheat, potato, vegetables. Increase of winter temperature can reduce the environmental suitability for wheat, potato and other temperate crops grown in Rabi season. During the winter and pre monsoon season (March-May) wheat and Boro grow. Therefore, changes of climate will severely decline grown of various winter crops.

- **Public health:** Increasing trends of heavy precipitation events might also cause a number of negative impacts on public health in Bangladesh. Many diseases of Bangladesh have direct relation with rainfall pattern. Hashizume et al. found that the number of non-cholera diarrhea cases in Dhaka increases both above and below a threshold level with high and low rainfall. Outbreaks of water-borne diarrhea diseases caused by parasites, like Giardia and Cryptosporidium, are associated with heavy rainfall events, therefore likely to become more frequent in Bangladesh with the increase of heavy precipitation events. Run off related to increased heavy precipitation events may cause increase of river water levels and flash flood. Water logging in urban areas as well as in northwest coastal zone of Bangladesh might be frequent phenomena. This might cause an increase of rotavirus Diarrhea in Bangladesh as it is directly associated with river level [21]

8. KNOWLEDGE GAPS AND FUTURE RESEARCH NEED

The final section of this Document addresses two questions: What lack of knowledge impedes the ability of Bangladesh to better adapt to climate change? What research should be done to acquire the necessary knowledge? There are several general areas in which research could pave the way to improved adaptation.

First, in some areas, there is a lack of fundamental knowledge concerning the relationship between climate change and socio-economic effects.

Second, the socio-economic effects of climate change in the urban environments of Bangladesh are of concern. Despite the future uncertainties, two trends are quite clear: Bangladesh will be warmer and more urbanized. Large, dense urban settlements are a relatively new phenomenon in Bangladesh.

Third, there is a need to examine the range of adaptive measures that are available for coping with environmental adversity. Perhaps this is most urgent for traditional adaptive mechanisms. These include not only technical adjustments like seed varieties and planting dates, but also measures of social reciprocity that serve to share the burdens of loss and the benefits of bounty.

Fourth, a key element in the development strategy of Bangladesh is its water control programme based on irrigation, flood, and drainage technologies. Studies are needed to assess how, and to what extent, traditional technologies are being adapted to changing climate pattern and socioeconomic conditions.

Fifth, there is a need to assess how customary behavior is being modified in response to changing social and environmental conditions. Research into the impact of modernization on customary behavior may help identify how best to integrate traditional and modern systems so that vulnerability to environmental and social stress is minimized — with or without rainfall variation.

Sixth, Rainfall and temperature data during the same period should be studied and establish its relationship with humidity.

Finally, Studies are needed of various forms of migration and resettlement of the landless to help anticipate the likely dimensions of problems that may arise if rainfall varies and sea level rises.

9. CONCLUSION

A study has been carried in this paper out to assess the trends of rainfall and rainfall related extreme events in Chittagong in Bangladesh which is one of the most vulnerable countries of the world to natural disaster. Increase of heavy rainfall events may cause more frequent floods especially in northwest region, more landslides in southeast hilly region, and frequent outbreaks of diarrheal diseases in Bangladesh. Most of the landslides in Chittagong hilly areas happen during the rainy season when rainfall intensity is very high. Therefore rainy seasons need to be monitored closely to assess the situation, especially in the landslide prone areas. In case of any potential landslide, people of the concerned localities need to be informed through early warning system. Awareness program should also contain the significance of proper land-use as well as sustainable land management. The circumspect government has developed and implemented various policy and strategy instruments to protect and improve various aspects of environment. As the rainfall is an important factor for agriculture, water resources, public health and economy of Bangladesh, it is hoped that the study in general will be more beneficial to a number of stakeholders of Bangladesh particularly disaster management, development and planning organizations.

References:

- [1] Islam, M.N.; and Uyeda, H. (2007). Use of TRMM in determining the climatic characteristics of rainfall over Bangladesh. *Remote Sensing of Environment*, 108(3), 264-276.
- [2] Islam, S. (2003). *Banglapedia: National Encyclopedia of Bangladesh*. Asiatic Society of Bangladesh.
- [3] Gregory, G. (1956). —Regional Variations in the Trends of Annual Rainfall Over the British Isles. *Geographical Journal*. Vol. 122, Part-III. Pp. 346-353.
- [4] Panabokke, C.R. and Walgame, A. (1974). —The Application of Rainfall Confidence Limits to Crop Water Requirements in Dry Zone Agriculture in Srilanka". *Journal of National Science*. Council, Srilanka, Vol.2, pp.95-113.
- [5] Parthasarathy, B. and Dhar, O.N. (1974). —Secular Variations of Regional Rainfall over India. *Quarterly Journal of Royal Meteorological Society*. No.100, pp. 265-257
- [6] Parthasarathy, B., Sontake, N.A., Monot, A.A., and Kothawale, D.R. (1987) "Drought-flood in the summer monsoon season over different meteorological subdivisions of India for the period 1871-1984", *Journal of Climatology*, 7, pp.57-70.
- [7] Benoit, P. (1977). —The Start of the Growing Season in Northern Nigeria. *Agricultural Meteorology*. Vol. 18, pp. 91-99.
- [8] Chowdhury, M.H. K. and Debsharma, S.K. (1992), "Climate change in Bangladesh – A statistical review", *Report on IOC-UNEP Workshop on Impacts of Sea Level Rise due to Global Warming*, NOAMI, held during 16-19 November 1992, Bangladesh
- [9] Stern, R.D., Dennett, M.D. and Garbutt, D.J. (1981). —The Start of the Rains in West Africa. *Journal of Climatology*. Vol. 1, pp. 59-68.
- [10] Stern, R. D. and Coe, R. (1982). —The Use of Rainfalls Models in Agricultural Planning. *Agricultural Meteorology*. Vol. 26. Pp.35-50.

-
- [11] Roy, M.K., Rahaman, S. and Paul, J.C. (1987). —Regional Variations in the Trends and Periodicities of Annual Rainfall over Bangladesh|| (Unpublished).
- [12] Nguyon, V.T.V. and Pandey, G.R. (1994). —Estimation of short-duration rainfall distribution using data measured at longer time scales||. *Water Science. Tech.*, Vol. 29, No. 1, pp. 39-45.
- [13] Rahman MR, Salehin M, Matsumoto J. (1997). —Trends of monsoon rainfall pattern in Bangladesh||. *Bangladesh Journal of Water Resources* 14–18: 121–138.
- [14] Ahmed R. (1989). —Probabilistic estimates of rainfall extremes in Bangladesh during the pre-monsoon season.|| *Indian Geographical Journal* 64: 39–53.
- [15] Karmakar S, Khatun A. (1995). —Variability and probabilistic estimates of rainfall extremes in Bangladesh during the southwest monsoon season.|| *Mausam* 46(1): 47–56
- [16] Karmakar, S. and Shrestha, M.L. (2000) “Recent climate change in Bangladesh”, *SMRC No.4*, SMRC, Dhaka.
- [17] Suhaila Jamaludin and Abdul Aziz Jemain (Jun 2007). “Fitting the statistical distributions to the daily rainfall amount in Peninsular Malaysia”. *Journal Teknologi*, 46(C) pp. 33-48.
- [18] Shamsuddin S (2009). —Rainfall variability and the trends of wet and dry periods in Bangladesh: *International Journal of Climatology*.” (www.interscience.wiley.com).
- [19] Mia, N.M. (2003) “Variations of temperature of Bangladesh”, In Proceedings of SAARC Seminars on Climate Variability In the South Asian Region and its Impacts, SMRC, Dhaka.
- [20] M. Previdi and B. G. Liepert (2008), “EOS”, Vol. 89, No. 21, 20 May 2008, Pages 193–200
- [21] Hashizume M (2007), “Association between climate variability and hospital visits for non-cholera diarrhoea in Bangladesh: effects and vulnerable groups”, *International Journal of Epidemiology* 2007, ;36:1030–103