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RAINFALL VARIATION IN BANGLADESH: TRENDS, FACTORS AND EFFECTS

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Abstract
Bangladesh has always been predominantly an agriculture based country. In early days, agricultural production was fully dependent on rainfall. Over the study period of recent 30 years, trend values of monsoon average rainfall in Chittagong, Dhaka and Rajshahi has risen as a consequence of the increase of the increase in rainfall. On the other hand, the trend value in Sylhet has declined with the decrease in rainfall. This paper has measured the correlation coefficients between rainfall and time for four stations: Chittagong, Dhaka, Rajshahi and Sylhet where correlation coefficient for Dhaka station and Sylhet station is maximum and negative respectively. This study indicates that climate change, global warming, destruction of hills etc. have disastrous effects on rainfall which is hampering not only the agricultural production but also the ecosystem. It is hoped that this research may be of help to the concerned organizations and experts working on this problem.
Keywords: rainfall variation, trend, correlation coefficient, global warming, public health, sea level rise.

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. Thus, a better understanding of rainfall variations has important implications for the economy and society of Bangladesh.

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2. CLIMATE OF BANGLADESH

Bangladesh occupies an area of 1, 47,570 square Kilometers, has a sub-tropical monsoon climate characterized by wide seasonal variations in rainfall, moderately warm temperatures and high humidity. Three distinct seasons can be recognized in Bangladesh from climatic point of view: (i) the dry winter season from December to February, (ii) the pre-monsoon hot summer season from March to May, and (iii) the rainy monsoon season which lasts from June to October (Rashid, 1991).

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. OBJECTIVE OF THE STUDY

The main objectives of the study are:

- Trend analysis of rainfall data
- Determine the correlation coefficient for four stations
- Identify the factors influencing rainfall and impacts of rainfall variation
- State the future research direction

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.

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.

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 and increasing trend. However, south Assam is the only sub-division where rainfall data show a negative trend.

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.

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.

Stern et al. (1982) have analyzed the daily rainfall data for Kano, Sholapur and Hydrabad, 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.

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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 30meteorological 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.

Nguyen and Pandey (1994) proposed a mathematical model to describe the probabi1ity 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.

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.

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

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.

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.

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.

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5. SOURCE OF DATA

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.

6. METHODOLOGY AND RESEARCH DESIGN

The climatic condition of Bangladesh is divided into four distinct atmospheric mechanisms and these mechanisms are classified as:

- The dry winter season from December to February.
- The pre-monsoon hot summer season from March to May.
- The rainy monsoon season from June to September.
- The post-monsoon autumn season which lasts from October to November.

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 according to the amount of annual rainfall. Thus four important meteorological station names Chittagong, Dhaka, Rajshahi and Sylhet have been selected from the four zones to analysis the rainfall data.

6.1. 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

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'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

i.e.

$$\hat{a} = \overline{y} - \hat{b}\overline{x}$$

and

$$\hat{b} = \frac{\sum (x-\overline{x})(y-\overline{y})}{\sum (x-\overline{x})^2}$$

Coefficient of determination, R^2 = (SS due to Regression)/ (Total SS)

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

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.

6.2. 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. The time series is made up of four components known as seasonal, trend, cyclical and irregular (Patterson, 1987). Trend is defined as the general movement of a series over an extended period of time or it is the long-term change in the dependent variable over a long period of time (Webber and Hawkins, 1980). 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. Therefore Tokua, Hoskins and Kiunga stations were excluded from this analysis. Trend is determined by the relationship between the two variables (temperature and time or rainfall and time or agriculture production and time).

To observe that the trend of monsoon average Rainfall for all the selected stations and trend values have been calculated by using least square method, the findings are presented in Table 4.1,Table 4.2, Table 4.3 and Table 4.4. Also trend values are plotted accordingly in Figure 4.1, Figure 4.2, Figure 4.3 and Figure 4.4 respectively.

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TABLE 4.1 - 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

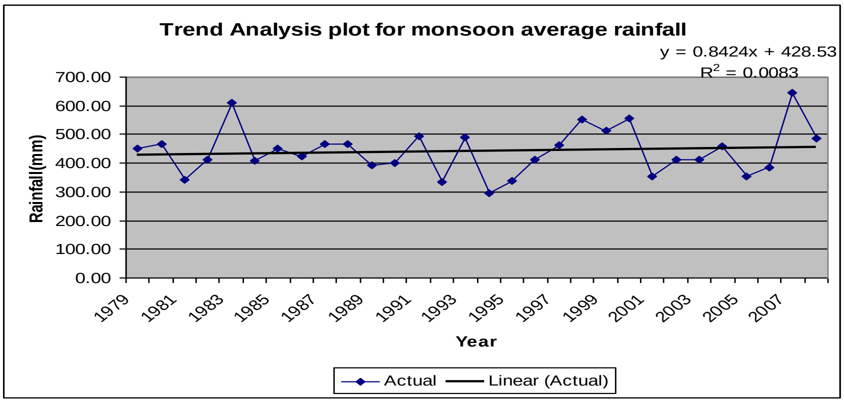

FIGURE 4.1 - TREND OF RAINFALL

The estimated trend in Table-4.1 and graphical representation in Fig-4.1 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.Figure 4.1: Trend Analysis Plot for monsoon average rainfall of Chittagong during period last 30 years (1979-2008).

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Figure 4.1 shows that the trend of rainfall for Chittagong is increasing which indicates there is a positive linear relationship between rainfall and time. The R2 value of about 0.0083 means that only 0.83% variation in rainfall is explained by time.

TABLE 4.2 - COMPUTATION OF TREND VALUES OF MONSOON AVERAGE RAINFALL OF DHAKA.

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	282.00	-29	260.51
1980	330.33	-27	262.72
1981	231.00	-25	264.93
1982	259.00	-23	267.14
1983	306.50	-21	269.34
1984	480.83	-19	271.56
1985	277.17	-17	273.77
1986	338.83	-15	275.98
1987	313.33	-13	278.19
1988	321.00	-11	280.40
1989	249.67	-9	282.61
1990	275.50	-7	284.82
1991	432.67	-5	287.03
1992	182.33	-3	289.24
1993	407.83	-1	291.45
1994	190.50	1	293.67
1995	251.83	3	295.88
1996	295.00	5	298.09
1997	274.83	7	300.30
1998	318.53	9	302.51
1999	390.00	11	304.72
2000	284.33	13	306.93
2001	263.50	15	309.14
2002	261.83	17	311.35
2003	234.00	19	313.56
2004	361.83	21	315.77
2005	397.33	23	317.98
2006	288.83	25	320.19
2007	428.33	27	322.40
2008	361.67	29	324.61

The estimated trend in Table-4.2 and graphical representation in Fig-4.2 of this study reflects that the monsoon average rainfall in Dhaka increasing over the time period. The simple regression coefficient indicates that on an average the rainfall in Dhaka is increasing 1.105 (b=1.105) per year.

Figure 4.2 shows that the trend of rainfall for Dhaka is increasing which indicates there is a positive linear relationship between rainfall and time. The R2 value of about 0.0182 means that only 1.82 % variation in rainfall is explained by time.

The estimated trend in Table-4.3 and graphical representation in Fig-4.3 of this study reflects that the monsoon average rainfall in Rajshahi increasing over the time period. The simple regression coefficient indicates that on an average the rainfall in Rajshahi is increasing 0.439 (b=0.439) per year.

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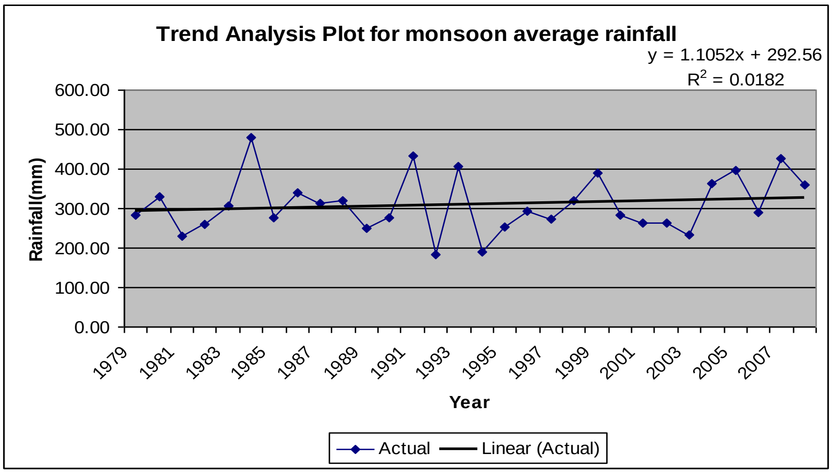

FIGURE 4.2 - TREND ANALYSIS PLOT FOR MONSOON AVERAGE RAINFALL OF DHAKA DURING PERIOD LAST 30 YEARS (1979-2008)

TABLE 4.3 - COMPUTATION OF TREND VALUES OF MONSOON AVERAGE RAINFALL OF RAJSHAHI.

Year (x)	Y=Average Rainfall(mm)	$t = \dfrac{x - \frac{1}{2}(1993+1994)}{\frac{1}{2}(Interval)}$	Trend values $\hat{Y} = \hat{a} + \hat{b}t$
1979	232.17	-29	211.62
1980	244.33	-27	212.50
1981	293.50	-25	213.38
1982	135.50	-23	214.25
1983	260.67	-21	215.13
1984	255.50	-19	216.01
1985	192.00	-17	216.89
1986	225.33	-15	217.77
1987	238.50	-13	218.65
1988	230.50	-11	219.53
1989	216.33	-9	220.41
1990	262.17	-7	221.28
1991	226.00	-5	222.16
1992	131.33	-3	223.04
1993	239.83	-1	223.92
1994	171.67	1	224.80
1995	220.33	3	225.68
1996	195.17	5	226.56
1997	313.00	7	227.44
1998	233.50	9	228.31
1999	308.67	11	229.19
2000	246.00	13	230.07
2001	226.50	15	230.95
2002	216.83	17	231.83
2003	212.67	19	232.71
2004	285.83	21	233.59
2005	209.83	23	234.47
2006	182.00	25	235.35
2007	319.67	27	236.22
2008	209.83	29	237.10

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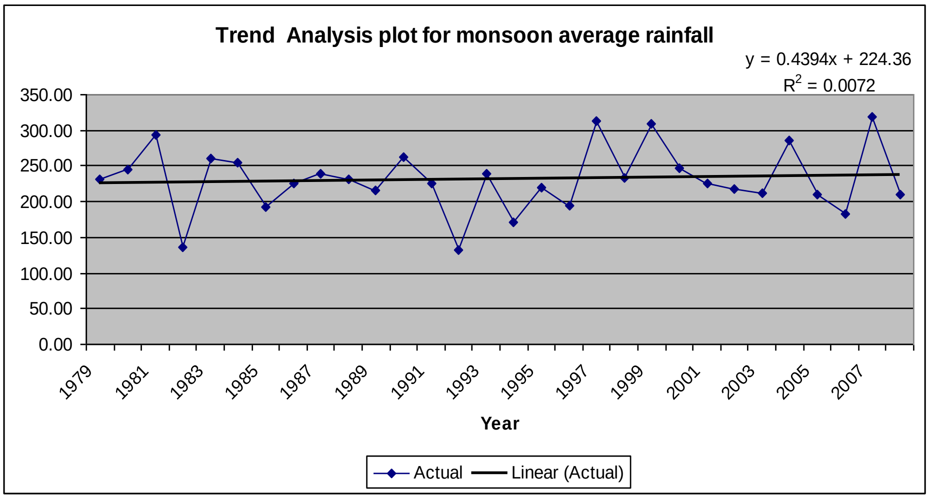

FIGURE 4.3 - TREND ANALYSIS PLOT FOR MONSOON AVERAGE RAINFALL OF RAJSHAHI DURING PERIOD LAST 30 YEARS (1979-2008).

TABLE 4.4 - COMPUTATION OF TREND VALUES OF MONSOON AVERAGE RAINFALL OF SYLHET.

Year (x)	Y=Average Rainfall(mm)	$t = \dfrac{x - \frac{1}{2}(1993+1994)}{\frac{1}{2}(Interval)}$	Trend values $\hat{Y} = \hat{a} + \hat{b}t$
1979	621.83	-29	697.92
1980	435.67	-27	692.87
1981	619.67	-25	687.83
1982	564.83	-23	682.78
1983	645.17	-21	677.73
1984	625.50	-19	672.68
1985	535.50	-17	667.63
1986	475.67	-15	662.58
1987	686.17	-13	657.53
1988	820.67	-11	652.48
1989	837.50	-9	647.43
1990	585.67	-7	642.38
1991	668.00	-5	637.33
1992	524.50	-3	632.28
1993	697.67	-1	627.23
1994	438.00	1	622.19
1995	579.33	3	617.14
1996	571.17	5	612.09
1997	547.83	7	607.04
1998	589.50	9	601.99
1999	513.00	11	596.94
2000	670.33	13	591.89
2001	509.83	15	586.84
2002	510.50	17	581.79
2003	511.33	19	576.74
2004	596.00	21	571.69
2005	571.83	23	566.64
2006	513.33	25	561.60
2007	606.33	27	556.55
2008	495.00	29	551.50

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Figure 4.3 show that the trend of rainfall for Rajshahi is increasing which indicates there is a positive linear relationship between rainfall and time. The R2 value of about 0.0072 means that only 0.72 percent variation in rainfall is explained by time.

The estimated trend in Table-4.4 and graphical representation in Fig-4.4 of this study reflects that the monsoon average rainfall in Sylhet decreasing over the time period. The simple regression coefficient indicates that on an average the rainfall in Sylhet is decreasing 0.439 (b=0.439) per year.

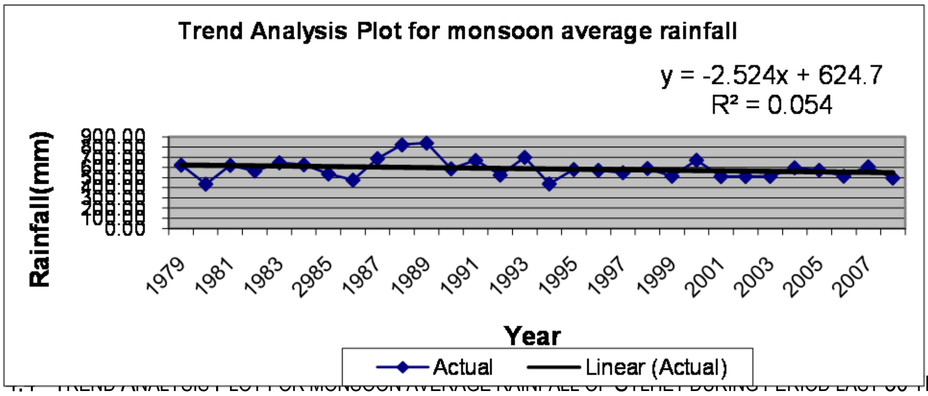

FIGURE 4.4 – TREND ANALYSIS PLOT FOR MONSOON AVERAGE RAINFALL OF SYLHET DURING PERIOD LAST 30 YEARS (1979-2008)

Figure-4.4 shows that the trend of rainfall for Sylhet is decreasing which indicates there is a negative linear relationship between rainfall and time. The R2 value of about 0.0534 means that only 5.43 percent variation in rainfall is explained by time.

The strength of the linear relationship between the variable and time was then calculated to determine the trend of rainfall. These relationships are measured by the correlation coefficient.

6.3. 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 (x1, y1), (x2, y2), ……….(xn, yn), the formula for computing the correlation coefficient is given by

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

The correlation coefficients for four stations were calculated using the above formula.

The results are shown in Table 4.5

TABLE 4.5 - CORRELATION COEFFICIENTS FOR RAINFALL AND TIME.

Station	Correlation Coefficients(r)
Chittagong	0.091
Dhaka	0.135
Rajshahi	0.084
Sylhet	-0.110

Table-4.5 shows that the negative relationship between rainfall and time at Sylhet station and the other station the relationship between rainfall and time is weak.

6.4 Testing significance of the correlation coefficient

In testing the significance of the correlation coefficient, the following null (H0) and alternative (H1) hypothesis were considered.

Hypothesis:

H0: $\rho = 0$

H1: $\rho \neq 0$

where, ρ is the population correlation coefficient.

The appropriate test statistics for testing the above hypothesis is

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

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

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

The P-values for four station of Bangladesh 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

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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 4.6 - TEST STATISTIC AND P-VALUES OF THE SELECTED STATION

Station	Observed values of t	Degrees of Freedom	P-value
Chittagong	0.484	28	0.632
Dhaka	0.721	28	0.477
Rajshahi	0.446	28	0.659
Sylhet	-0.586	28	0.563

Table-4.6 shows that the P-values are large for all the selected station and therefore the null hypothesis is not rejected. This implies that the correlation coefficient for rainfall is statistically insignificant though it is slightly decreasing in Sylhet station.

7. FINDINGS AND ANALYSIS

7.1. Status of current situation

The trend for Chittagong, Dhaka and Rajshahi is increasing which indicates there is a positive relationship between time and rainfall. Correlation coefficient for rainfall and time in Chittagong, Dhaka and Rajshahi are 0.091, 0.135 and 0.084 respectively. Among the stations, the value of correlation coefficient in Dhaka is maximum. On the other hand, the trend of monsoon average rainfall in Sylhet is decreasing which shows the negative relationship between rainfall and time. Correlation coefficient in Sylhet is -0.110, which is negative.

The P-Values for Chittagong, Dhaka, Rajshahi and Sylhet station are 0.632, 0.477, 0.659 and 0.563 respectively. This indicates that the correlation coefficients for all stations are large though it is slightly decreasing in Sylhet station.

7.2 Factors influencing rainfall and impacts of rainfall variation

Liable Factors for rainfall variation

- 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

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on the effective rainfall. Reason behind increasing rainfall in Chittagong, Dhaka and Rajshahi 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 (CO2) levels .The result of this CO2-induced reduction in long wave efficiency (or emissivity) is that a smaller increase in latent heating and thus rainfall increases. (M. Previdi and B. G. Liepert , 2008)
- Destruction of hills: Rainfall is decreasing at Sylhet region. The reason behind this is destruction of hills. Major effects of hill cutting hills are: i) Deforestation and desertification ii) Ecological imbalance and climate change. Growth of plants and trees from the cut portion of the hill, takes long time or almost absent in many cases. Such deforestation can decrease rainfall. 'United Nations Convention to Combat Desertification' (UNCCD) defined desertification. In the definition desertification is understood as 'land degradation in dry lands', and one of the main indicators of land degradation is change in the productivity of the vegetation cover. Desertification is occurred due to climate change. It is liable for decreasing rate of rainfall in Sylhet region. For rainfall, lifting of moist air mass is necessary for

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condensation into droplet and air formation. In this case, hills act as a barrier, where the moist air, after being obstructed, lift upward and gradually loose it's temperature to condense enough to form cloud. This is the main reason of the high intensity of rainfall at the Sylhet region. Due to destruction of hills, now moist airs are not being obstructed such a way and the amount of rainfall in Sylhet region is decreasing. This will result in a massive change in the eco-system of tea plantation which requires heavy rainfall (Md. Sirajul Islam,G M Jahid Hasan,Md. Aktarul Islam Chowdhury,2005)

Impacts of rainfall variation

- 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.
- Sea level rise: The IPCC (Intergovernmental Panel on Climate Change) has also collected data that shows that global warming is affecting weather and the environment in a number of ways causing further problems: Sea level due to melting polar ice caps and seawater expansion (due to it being warmer) has been rising between 1993 and 2003 at a rate of 3.1 mm per year. Furthermore rainfall patterns have been changing with increased droughts in some areas and heavier rain in others; glaciers and snow have been melting increasing water in rivers at certain times; winds are increasing in power; and ocean temperatures have been rising (Alley et al, 2007). In Bangladesh, the impact of sea-level rise may be worsened by other effects of global warming, such as variable precipitation, more frequent droughts and floods, and shrinking of the glaciers that supply water to the rivers of the delta. (Nishat, A. 2008) Reduced rainfall during the dry season, for example, can increase the salinity of rivers through encroaching seawater that moves upstream during periods of low flow (Mohal, N., Z.H. Khan, and N. Rahman. 2006)
- 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 (Hashizume et al.2007).

- Imbalance in Ecosystem: Decreasing rate of rainfall will result in a massive change in the ecosystem of tea plantation, which requires heavy rainfall. If the rainfall in Sylhet region decreases in this pattern and Meghalaya region increases, for the upstream cross sections of the rivers in the Sylhet region, this excess flow will appear as unusual over the capacity of the river cross sections, causing flash flood. It has been reported by Bangladesh Water Development Board (BWDB) that the number of flood increases nowadays in this region. On the other hand, Significant decreasing trends in annual and pre-monsoon consecutive dry days may help to increase the crop productivity and reduce the pressure on groundwater for irrigation in Bangladesh.

8. CONCLUSIONS

A study has been carried in this paper out to assess the trends of rainfall and rainfall related extreme events in Bangladesh which is one of the most vulnerable countries of the world to natural disaster. Increasing trends in heavy precipitation days are observed in Bangladesh with the increase of average annual and pre-monsoon rainfall which might have number of negative implications. 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. Significant decreasing trends in annual and pre-monsoon consecutive dry days may help to increase the crop productivity and reduce the pressure on groundwater for irrigation in Bangladesh. 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.

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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 rainfall variation? 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 rainfall variation and socio-economic effects.

Second, the socio-economic effects of rainfall variations 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 rainfall 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.

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.

Future research direction

Fulfilling the research needs noted above requires interdisciplinary research (integrating social sciences and natural sciences) aimed at developing an optimum strategy for reducing the vulnerability of Bangladesh to rainfall variation. This research — which ought to be a major focus of future research design— would help to ascertain the priorities that could be given to various kinds of activities.

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A general framework for pursuing this research could take the form indicated in below. It aims to identify the main interactions between two main elements for reducing vulnerability. These elements include:

A. Policies aimed at socio-economic development through:

- reducing pollution
- reducing population growth
- reducing global warming
- improving technical training
- improving health care
- reducing hill cutting

B. Policies aimed at reducing vulnerability to extremes given present rainfall pattern through:

- improving irrigation procedure
- constituting Cyclone Recovery & Restoration Project
- taking Emergency preparedness
- improving Land-use management
- Disaster preparedness and management procedures
- taking Water management programme
- taking Proper drainage system
- Planning forestation programmes, both by the public and the private sectors.

Limitations of the Study

The present study has been affected by a number of limitations. The rainfall data for Chittagong, Dhaka, Rajshahi and Sylhet stations have been considered to represent the whole of Bangladesh. Although Chittagong, Dhaka, Rajshahi and Sylhet are four administrative divisions, the rainfall data for these stations may not be representative of Bangladesh. The daily rainfall data for some of the months at different years are missing. These missing data are substituted by the average values for the respective months.

The daily rainfall data for some of the days at different months are missing. These missing data are substituted by zero. The study on the patterns of daily rainfall occurrences involves strong assumptions. To develop the Markov chain model for daily rainfall occurrences we assumed that the day before the initial day is non-random; practically it may not be true. Further, a day in which at least 0.1mm. rainfall has occurred is considered as a wet day and dry day otherwise. If 0.1mm. of rainfall occurs preceding and following long dry spell, it may not have any properties of a wet day. Again, if 0.1mm. of rainfall occurs preceding and following a long wet spell, it may have countable effect on agricultural crops (Sarkar, 1987).

REFERENCES

Ahmed R. (1989). "Probabilistic estimates of rainfall extremes in Bangladesh during the pre-monsoon season." *Indian Geographical Journal* 64: 39–53.

Alley(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.

Benoit, P. (1977). "The Start of the Growing Season in Northern Nigeria". Agricultural Meteorology. Vol. 18, pp. 91-99.

Deshmukh D. T., Lunge H. S.(2012)." Impact of Global Warming on Rainfall, And Cotton Lint With Vulnerability Profiles of Five Districts In Vidarbha, India": *INTERNATIONAL JOURNAL OF SCIENTIFIC & TECHNOLOGY RESEARCH* VOLUME 1, ISSUE 11, DECEMBER 2012

Gregory, G. (1956). "Regional Variations in the Trends of Annual Rainfall Over the British Isles". *Geographical Journal.* Vol. 122, Part-III. Pp. 346-353.

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

Jamaludin S and Abdul Aziz J (Jun 2007). "Fitting the statistical distributions to the daily rainfall amount in Peninsular Malaysia". *Journal Technology*, 46(C) pp. 33-48.

Karmakar S, Khatun A. (1995). "Variability and probabilistic estimates of rainfall extremes in Bangladesh during the southwest monsoon season." *Mausam* 46(1): 47–56

M. Previdi and B. G. Liepert (2008), "*EOS*", Vol. 89, No. 21, 20 May 2008, Pages 193–200

Md. Sirajul Islam,G M Jahid Hasan,Md. Aktarul Islam Chowdhury,2005. "Destroying hills in the northeastern part of Bangladesh: a qualitative assessment of extent of the problem and its probable impact." *Int. J. Environ. Sci. Tech.* Winter 2006,Vol. 2, No. 4, Pages:301-308

Mohal, N., Z.H. Khan, and N. Rahman. 2006. "Impact of sea level rise on coastal rivers of Bangladesh" . Bangladesh: Coast, Port and Estuary Division, Institute of Water Modelling. Online at www.riversymposium.com/ 2006/ index.php? element=06MOHALNasreen. Accessed May 17, 2010

Management Research and Practice
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ISSN
2067- 2462

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.

Nishat, A. 2008. “Climate change and water management in Bangladesh. Conference on Global Climate Change and Its Effects” : International Union for Conservation of Nature, Dhaka. Online at http://www.wamis.org/ agm/ meetings/ rsama08/ S308-Nishat_Climate-Change-Water-Mgmt-Bangladesh.pdf. Accessed May 17, 2010.

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.

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

Rahman MR, Salehin M, Matsumoto J. (1997). “Trends of monsoon rainfall pattern in Bangladesh”. *Bangladesh Journal of Water Resources* 14–18: 121–138.

Roy, M.K., Rahaman, S. and Paul, J.C. (1987). “Regional Variations in the Trends and Periodicities of Annual Rainfall over Bangladesh” (Unpublished).

Shamsuddin S (2009). “Rainfall variability and the trends of wet and dry periods in Bangladesh: *International Journal of Climatology.”* (www.interscience.wiley.com).

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.

Stern, R. D. and Coe, R. (1982). “The Use of Rainfalls Models in Agricultural Planning”. *Agricultural Meteorology*. Vol. 26. Pp.35-50.

www.wbiconpro.com/239-Rahman,S.pdf

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