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Time Series, Factors and Impacts Analysis of Rainfall in North-Eastern Part 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 Sylhet have decreased. This paper has measured the correlation coefficients between rainfall and time for Sylhet, where correlation coefficient for Sylhet is negative. In order to check the strength of linear relationship between rainfall and time, P-value has been measured. Due to various factors of Sylhet region of Bangladesh, there is a growing need to study the rainfall pattern, and also frequency of the heavy rainfall events. This study was checked annual average rainfall of 30 years for this region. It is hoped that this research may be of help to the concerned organizations and experts working on increasing rainfall problem in Chittagong.

Index Terms- rainfall variation, trend, correlation coefficient, t-test, P-value

I. Introduction

Bangladesh, is primarily a low-lying plain of about 144,000 km2, situated on deltas of large rivers flowing from the Himalayas, has a sub-tropical humid climate characterized by wide seasonal variations. 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].

II. NORTH-EASTERN PART OF BANGLADESH

Sylhet, the north-eastern administrative division of Bangladesh, located at 24°53´ latitude and 91°52´ E longitudes, has a number of topographical features like rivers, hills and hillocks (tilas), haors (wetland) and high flood plain; which made it quite different from the rest of the parts of Bangladesh. Hilly Sylhet region not only plays an important role in the socio-economic development of Bangladesh but also important for ecological balance of the country. Beautiful panorama of the region with vast reserve forest, intense tea gardens and growing rubber gardens in the hillocks, lakes and wetlands as well as sands and stones of the border areas made it attractive for tourists from both home and abroad. Among the topographical features of the region, hills are the most dominating one, which is determining its climatic and morphological features. Heavy rainfall, tea garden, dense bamboo and cane bushes, high flood plain and the flashy rivers; all the features are very related and contributed by the hills of this region, e.g., [3]. Haor basin extends from two rivers to the high plain of central Sylhet. The basin generally goes under water for several months during monsoon. The flood plain is higher at this region than the rest of the part of the country.

Northern branch of river Barak (comes from India) renamed as ‘Surma’ which is one of the main river of Bangladesh passed through Sylhet city. Southern branch of Barak gets the name Kushiara in Bangladesh, which is another major river of Sylhet. Surma and Kushiara make unification as Kalani, which is renamed as Meghna and passes through the central portion of the country and finally merges with the Bay of Bengal. Other important rivers are: Mogra, Dhanu, Boulai and Ghorautra. Main characteristic of rivers in this region is flashy and flash flood occurs frequently during May to the middle of October [3]. The networks of the rivers, streams and channels overflow in the monsoon and fill the haors. Any change of the hydro-climatic pattern in this region will significantly affect the balance among these natural features and also other parts of the country. Hence, a comprehensive understanding of the rainfall pattern in this region is greatly needed.

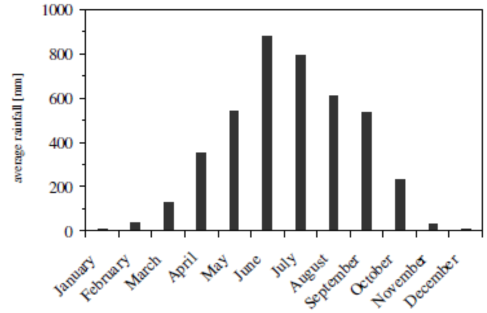

Figure 2.1: Average monthly rainfall in Sylhet region (1957-2006)
Source: Bangladesh Water Development Board (BWDB)

III. OBJECTIVE OF THE STUDY

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

IV. 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.

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.

V. MATERIALS AND METHODOLOGY

5.1 Data collection and data range:

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. Thus one important meteorological station, Sylhet has been selected from the four zones to analysis the rainfall data.

5.2 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

i.e.

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

and

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

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

5.3 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 the selected stations and trend values have been calculated by using least square method, the findings are presented in Table 6.1. Also trend values are plotted accordingly in Figure 6.1.

The estimated trend in Table-6.1 and graphical representation in Fig-6.1 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.

5.4 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

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

The correlation coefficients for Sylhet station was calculated using the above formula.
The results are shown in Table 6.2

5.5 Testing Significance of the Correlation Coefficient

In testing the significance of the correlation coefficient, the following null ($H_\circ$) and alternative (H1) hypothesis were considered.

Hypothesis:

$H_\circ$: ρ = 0
H1: ρ ≠ 0

Where, ρ is the population correlation coefficient.

The appropriate test statistics for testing the above hypothesis is

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

VI. RESULTS AND DISCUSSION

Table 6.1: Computation of trend values of monsoon average rainfall of Sylhet.

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	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

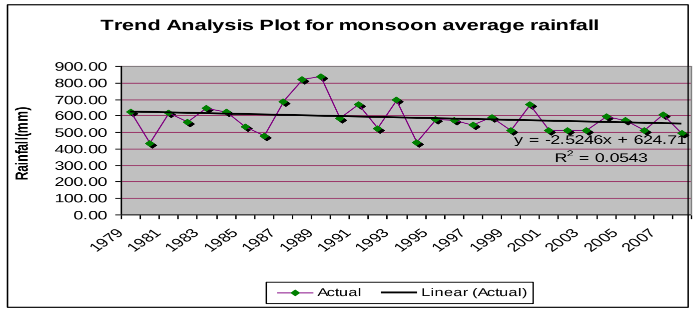

Figure 6.1: Trend Analysis Plot for monsoon average rainfall of Sylhet during period last 30 years (1979-2008)

Figure-6.1 shows that the trend of rainfall for Sylhet is decreasing which indicates there is a negative linear relationship between rainfall and time.

The R^2 value 0.0543 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.

Table 6.2 Correlation coefficients for rainfall and time.

Station	Correlation Coefficients(r)
Sylhet	-0.110

Table-6.2 shows that the negative relationship between rainfall and time at Sylhet station

Table 6.3 Test statistic and P-value of the selected station

Test statistic and P-value	Sylhet station
Observed values of t	-0.586
Degrees of Freedom	28
P-value	0.563

Table-6.3 shows that the P-values are large for 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.

VII. FACTORS BEHIND DECREASING RAINFALL

7.1 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 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)

7.2 Global warming:

Studies in different parts of the world indicate that global warming has altered the precipitation patterns and resulted in frequent extreme weather events, such as rainfall variation, floods, droughts and rainstorms, etc. [18-20] Due to the global warming, in South Asia, most of the climate models project a decrease in precipitation during the dry season and increase during the monsoon season (Christensen et al. 2007)

VIII. IMPACTS OF DECREASING RAINFALL

Sylhet, as a north-eastern district of the country experiences flash flood, as it is close to Meghalaya of India which is mainly hilly area.

8.1 Flash flood:

River cross-section builds up based on the catchments pattern and the amount of rainfall over it. If rainfall in Sylhet region decreases 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. [4]

Heavy rains in south-eastern and north-eastern Bangladesh, starting on June 25, 2012 and lasting over five days have caused floods and catastrophic landslides, leaving at least 118 dead (as of June 29, 2012) and over 300,000 people without secure accommodation. Flash Floods set off by heavy rains and upstream torrents from Meghalaya in India have swamped vast stretches of land in Sylhet and other nearby districts of the country, leaving thousands of people marooned. In addition, there is a high potential to deteriorate the flood condition in Sylhet as the onrush of water from upstream is very likely to inundate most of the sub-districts located near to Indian border. As the river beds of surma and kushiara and their tributaries are silted up, so the prolonged water beyond danger limit might cause huge affect to Sylhet District.[22]

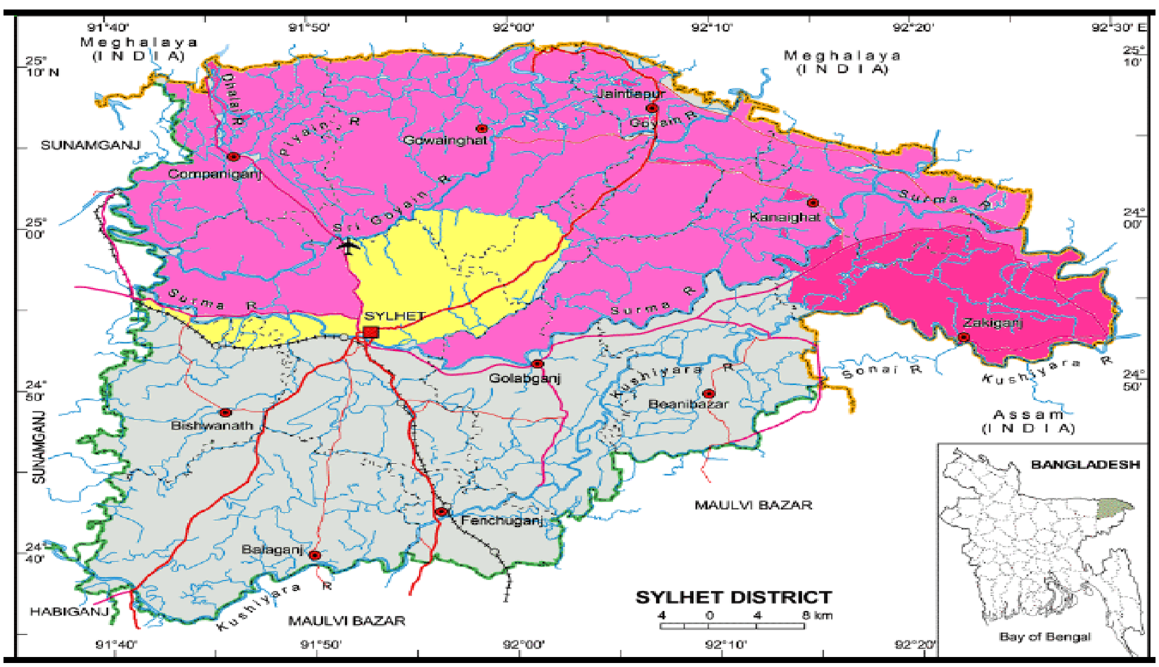

Figure 8.1: Flood Affected Area Profile, 2012

8.2 Imbalance in Ecosystem: Decreasing rate of rainfall will result in a massive change in the ecosystem of tea plantation, which requires heavy rainfall. 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. [4]

Part of the old Meghna esturine, old Bramhaputra, and eastern Surma- Kushiyara flood plains and Sylhet basin may also be affected. Large volume of sediments gets settled in the paddy lands and in the river channels. Flash floods normally damages Boro paddy in the depression sites and also seedlings of aman crop and vegetables. [24]

8.3 Soil erosion and landslides: Changes in distribution and intensity of rainfall pattern observed over years in hilly regions might be attributed to global climate change. This has accelerated soil erosion and land slides. [23]

8.4 Unemployment: Majority of the people living in vulnerable areas are engaged either in crop production and/or fishing. They frequently remain unemployed due to tidal flooding and other natural hazards resulting in food insecurity.[23]

IX. CONCLUDING SUSTAINABLE MANAGEMENT OPTIONS

1. Landslide vulnerability assessment and zoning is a prerequisite for sustainable management.

2. City planning, land use and utilization must adhere to the recommended land zoning and relevant policy and legal provisions.

3. Most of the landslides in Sylhet 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.

4. Awareness program should also contain the significance of proper land-use as well as sustainable land management.

5. A recognized important element in adaptation to increased floods caused by climate change is and adequate flood forecasting system able to provide reliable forecasts during floods with sufficient lead time.

6. Modification of buildings and structures and their immediate surroundings to reduce damage in flooding.

7. Actions undertaken during floods to prevent damage to and failure of flood control structures are known flood fighting. Flood fighting is an emergency measure of mitigating flood impacts on society and environment, particularly when flood control structures have proved ineffective or failed.

8. Evacuation is essential where the buildings or other features do not provide a safe place of refuge during a flood.

9. In the contest of climate change government should preserve a good volume of money to assistant and flood relief as an adaptive measure.

10. Flood insurance can be implemented to manage the flood damage costs. It is presently available in many countries with well-developed insurance markets.

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