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FREQUENCY STRUCTURE OF MAJOR RAINFALL EVENTS IN THE NORTH-EASTERN PART OF BANGLADESH

G. M. JAHID HASAN*, RAQUIBUL ALAM,
QUAZI NIRZZHORUL ISLAM, MD. SAKHAWAT HOSSAIN

Department of Civil and Environmental Engineering, Shahjalal University
of Science and Technology, Sylhet-3114, Bangladesh
*Corresponding Author: jahid01@yahoo.com

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. The distribution of rainfall in time and space is, therefore, an important factor for the economic development of a country. Due to rapid urbanization in various parts of the north-eastern 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 monthly average rainfall from daily records of last 50 years for this region. In order to check the major events, time history of monthly rainfall data were transformed into frequency domain using the Fast Fourier Transform (FFT). Estimated peak frequency (11.98 month) depicts that major rainfall events of a year are occurring earlier than the previous year. The variability of rainfall in time scale was also checked from filtered signals, which is very useful for long-term water resources planning, agricultural development and disaster management for Bangladesh.

Keywords: Bangladesh, flood, rainfall, rainfall frequency analysis, Sylhet.

1. Introduction

Bangladesh is an agriculture-based country where about 80% of its 145 million people are directly or indirectly engaged in a wide range of agricultural activities [1], where rainfall is one of the important natural factors for agricultural production. The variability of rainfall and the pattern of extreme high or low precipitation are important for the agriculture as well as the economy of the country. The rainfall is changing on both the global [2, 3] and the regional scales [4-6] due to global warming, which is well established. The implications of these changes are particularly significant for Bangladesh where different kinds of hydrological disasters are occurring frequently [7].

Bangladesh receives some of the heaviest rainfall in the world [8]. The heavy rainfall over this area is an important part of the atmospheric heat source that controls Asian summer monsoon circulations [9, 10]. Heavy rainfall often causes flooding in Bangladesh and the country is one of the most flood-prone countries in the world due to its geographic position [1]. Drought in north-western part and heavy rainfall in the north-eastern part of the country is also a common phenomenon [7, 11]. The country experienced a number of severe dry and wet periods in past 50 years. Heavy rainfall in the monsoon of 2007 together with the flood water by Himalayan-fed Rivers resulted in severe flood in Bangladesh which affected more than 9 million people. On the other hand, drought due to low precipitation in 1994–1995 led to a decrease in rice and wheat production by 3.5×10^6 MT [12].

The Intergovernmental Panel on Climate Change (IPCC) termed Bangladesh as one of the most vulnerable countries in the world due to climate change (web address: http://www.ipcc.ch/publications_and_data/publications_ipcc_fourth_assessment_report_wg2_report_impacts_adaptation_and_vulnerability.htm. Hydrological changes are the most significant impacts of climate change in Bangladesh. It has been predicted that due to climate change, there will be a steady increase in temperature and rainfall of Bangladesh. 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 floods, droughts and rainstorms, etc. [13-15]. The study of rainfall variability and the trends of major events are therefore important for long-term water resources planning, agricultural development and disaster management in Bangladesh in the context of global climatic change.

Although a number of studies have been carried out on rainfall patterns [11, 16-21], only very few works have been found on rainfall trends and extremes in Bangladesh. Rahman et al. [22] used trend analysis to study the changes in monsoon rainfall of Bangladesh and found no significant changes. Ahmed [23] estimated the probabilistic rainfall extremes in Bangladesh during the pre-monsoon season. Karmakar and Khatun [24] 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. May [25] reported that the frequency of wet days has noticeably increased over the tropical Indian Ocean. He predicted that intensity of heavy rainfall events in Bangladesh will be increased in the future. Immerzeel [26] predicted accelerated seasonal increases in precipitation in the 21st century with strongest increase in monsoon in the Brahmaputra basin. The pattern of major rainfall events as well as its monthly variability from the daily rainfall records has been analyzed in this study for the north-eastern part of Bangladesh.

2. Hydro-Climatic Condition of Bangladesh

Bangladesh, is primarily a low-lying plain of about 144,000 km^2, 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 [27]. Rainfall variability in space and time is one of the most relevant characteristics of the climate of Bangladesh. Spatial distribution of rainfall in Bangladesh is shown in Fig. 1. Rainfall in Bangladesh varies from 1400 mm in the western part to more than 5000 mm in the eastern part of the country. Huge amount of rainfall in the north-east region is caused by the additional uplifting effect of the Meghalaya plateau.

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 [1]. Topography of the country is extremely flat with some upland in the north-eastern and the south-eastern part. The plain land lies almost at sea level along the southern part of the country and rises gradually towards north. Land elevation in the plain varies from 1 to 60 m above the sea level from south to north. Hilly areas are located in the south-eastern and north-eastern regions, and terrace land can be found in the north-western and central regions of the country. The rainfall distribution in Bangladesh reflects topography. For example, Sylhet (north-eastern) and Chittagong (south-eastern) regions are the two distinctly wet belts separated by a wide dry zone. The two wet belts are the hilliest portion of the country. Basic reason for changing seasons is the differential heating of vast areas covered by land and water, which causes the monsoons, and the variations in the rainfall.

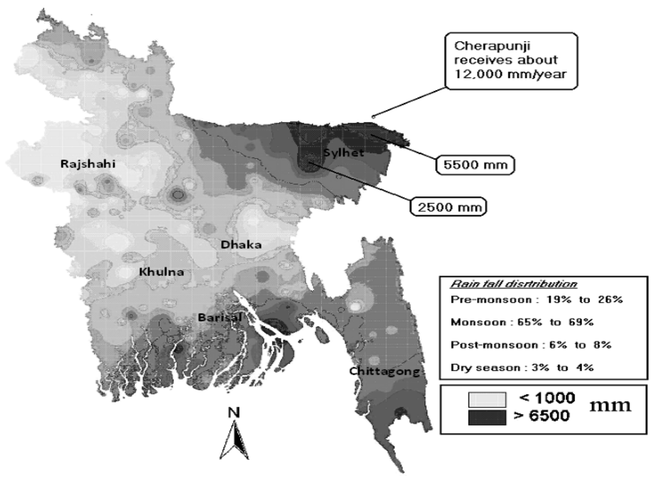

Fig. 1. Distribution of Average Rainfall in Bangladesh after [28].

3. Study Area and Materials

3.1. North-eastern part of Bangladesh

Sylhet, the north-eastern administrative division of Bangladesh, located at 240˚53′ latitude and 910˚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., [29]. 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 [29]. 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.

3.2. Collection of rainfall data

Bangladesh Water Development Board (BWDB) is the principal organization which is responsible for all hydro-meteorological data for Bangladesh. With a wide network of rainfall stations distributed throughout the country, daily rainfall records are the only available format at BWDB. For this study, rainfall data of 50 years started from 1957 for Sylhet station was collected from their data record. The daily record seems very helpful, though the continuity of the data was hampered by some missing records (approximately 2%).

4. Analysis and Discussion

The monthly and annual mean rainfall variability in this region and their frequency distribution were analyzed from the collected daily records and discussed in the following sections.

4.1. Average distribution of rainfall

The continuity of the daily rainfall records was disrupted by some missing data which was checked carefully and estimated those by averaging from the available data for a particular month. Usual procedure for estimating the missing records (i.e., weighted average interpolation) was not possible because of single point consideration. To develop the monthly average rainfall, the rainfall data of each day of a corresponding month in the data series were summed and then divided by the total number of available rainy days within that month. The obtained amount of rainfall was then multiplied by the actual number of days of the corresponding month, results rainfall for that particular month. Average rainfall estimated from the available data for a particular month is considered as the rainfall of the missing days which is the main assumption considered in this study. However, this assumption was not applied for dry periods and also when dry days were more than 10 in a particular month.

Figure 2 shows average rainfall in mm of the Sylhet area in different months. The average monthly variation was estimated from the rainfall record of last 50 years (1957~2006). The assumption for estimating missing records may over predict for a particular month, however, the monthly distribution looks quite acceptable. Month of July is getting highest amount of rainfall which can be observed from the figure.

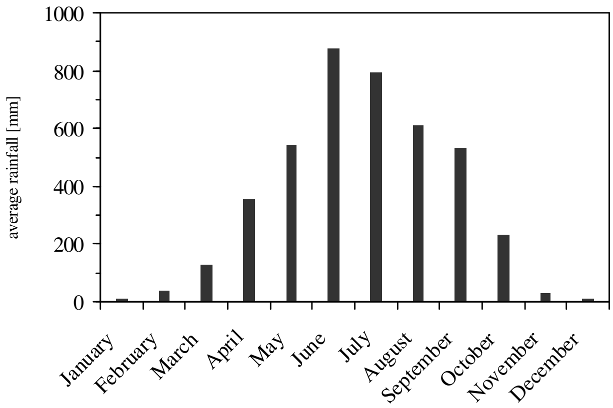

Fig. 2. Average Monthly Rainfall for Sylhet Region which has been Estimated Using 50 Years Daily Rainfall Records (1957~2006).

Table 1 compares the average monthly rainfall of Sylhet region estimated in this study from 50 years record with that of Bangladesh. The average rainfall for Bangladesh was collected from [28]. The table indicates that the average rainfall in the north-eastern part is much higher than the average rainfall in Bangladesh in most of the months.

Table 1. Comparison between Monthly Variation of Rainfall in Sylhet Region and Bangladesh.

Month	Average rainfall in Bangladesh (mm)	Average rainfall in Sylhet (mm)
January	17	10
February	28	37
March	52	126
April	117	354
May	230	542
June	420	878
July	460	792
August	470	610
September	300	532
October	300	229
November	55	30
December	5	11

4.2. Annual rainfall distribution

Figure 3 shows yearly rainfall in Sylhet region for last 50 years started from 1957. The interpolated rainfall data was used for the estimation. There was some missing in the data length of years 1957, 1960 and 1961. The vertical solid line indicates the average rainfall, which is 4260 mm. Yearly rainfall above the average value may consider as an extreme situation which is prone for flood occurrences.

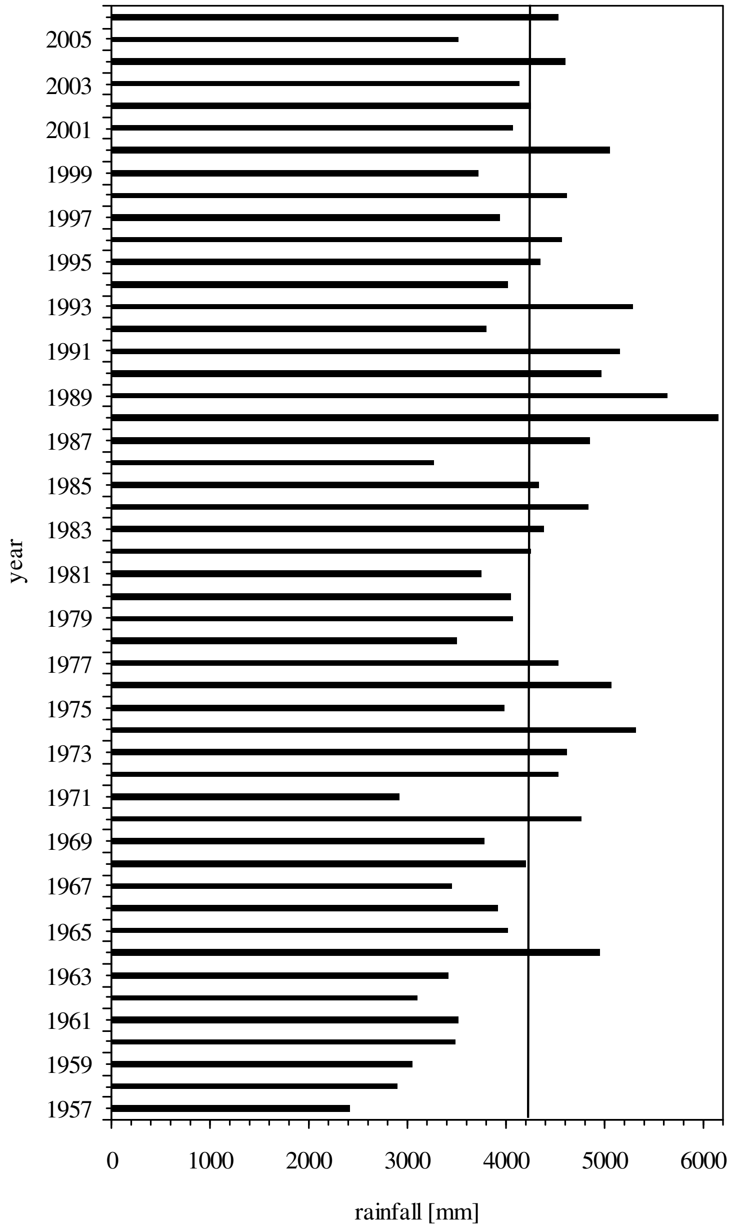

Fig. 3. Annual Rainfall of the Sylhet Area for Last 50 years.
(Vertical solid line indicates the average rainfall (~ 4260 mm), which is averaged between 1957 and 2006. Yearly rainfall above the average value can be considered as extreme situation which is prone for flood occurrences.)

4.3. Spectral analysis of rainfall data

Temporal variations of monthly rainfall data were analyzed with the Fast Fourier Transform (FFT) to check the frequency structure of the rainfall variation. A sequence of 512 months started from April, 1957 to November, 1999 was used in the analysis and the dominating frequency corresponding to highest spectral density was determined. Monthly variation of rainfall is shown in Fig. 4. The time series looks quite smooth with periodic variation which is acceptable and seems that the missing data estimation did not make any severe mischief. Average of the temporal variation of the 512 months rainfall record is 350 mm. It seems from the time series that there is a major rainfall event (above the average value) almost every year.

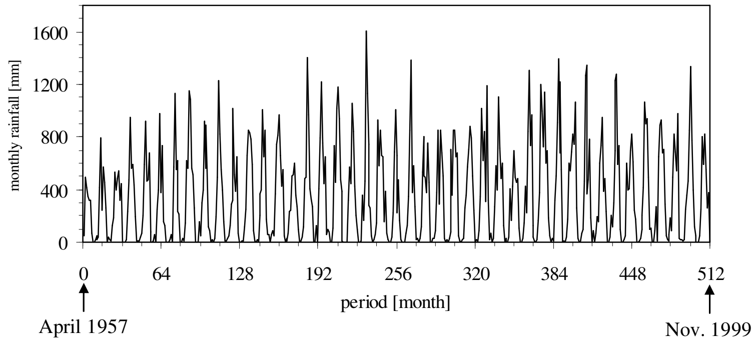

Fig. 4. Time History of Monthly Rainfall.

The spectrum of monthly rainfall variation is shown in Fig. 5, which was normalized between 0 and 1. The peak frequency fp of 0.084 month-1 (11.98 month) is observed from the spectra, which speculates almost every year there is a peak rainfall event. However, the peak frequency is slightly less than 12 month indicates the major rainfall events are occurring earlier to some extent in a year compare to the previous year. Probable reason of shifting the major rainfalls is climate change; however, without further analysis it is not possible to conclude here. The frequency structure is not showing any significant value in its lower frequency zone (less than a year). Hence, the FFT analysis captures successfully the major rainfall events, but failed to indicate extreme rainfall events.

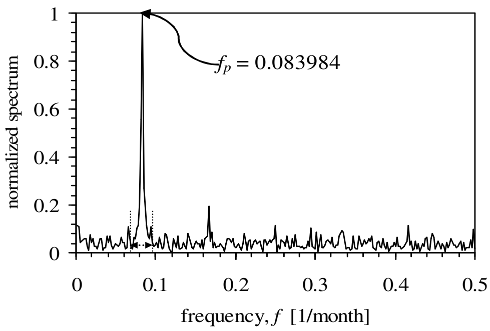

Fig. 5. Normalized Spectra Estimated from Monthly Rainfall Variation.
(Dotted band indicates the frequency range used for filtering.)

Figure 6 shows monthly rainfall variation after being filtered through a band pass filter (0.070 to 0.097 month-1) and compared with the original monthly variation. Both the data series was normalized between 0 and 1 by the difference of the maximum and minimum values. The figure shows that the filtered signal follows reasonably well with the passage of major rainfall events. The filtered signal can be used for prediction of major events such as heavy rainfall or inundation issues.

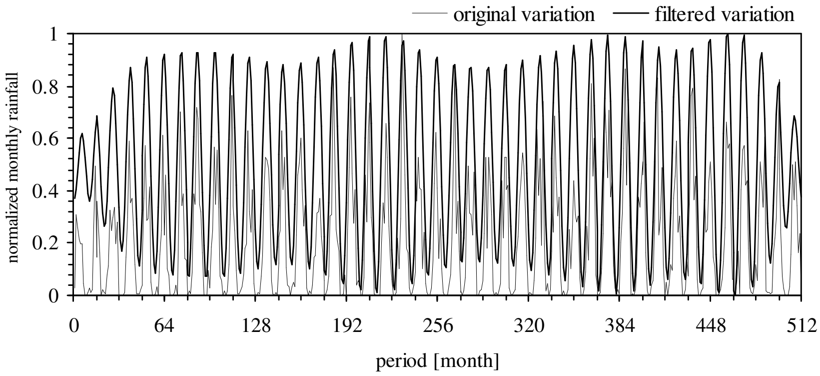

Fig. 6. Comparison between Original Monthly Rainfall Variation and Filtered (with a Band Pass Filter 0.070 to 0.097 Month^{-1}) Variation. Both the Data Series was Normalized between 0 and 1.

4.4. Extreme rainfall events

It is observed that annual rainfall of the north-eastern Bangladesh has a relation with flood occurrence of the country. In cases of all severe floods occurred in Bangladesh, even in the recent years, annual rainfall of this region in Bangladesh were well above its normal average magnitude (4330 mm). Table 2 shows the picture of recent flood havoc and the annual rainfall of this region in Bangladesh. It is noted that Sylhet was out of the flooded area during these flood events, however, the region receives huge rainfall during those events. The table depicts that annual rainfall reduces to 4603 mm in 2004 from 4838 mm in 1984 but damages has increased many times.

Table 2. Recent Flood Records with the Annual Rainfall of the North-Eastern Part of Bangladesh.

Severe floods in the last 25 years in Bangladesh		
Year of flood events	**Annual rainfall (mm) in the Sylhet region**	**Impact**
1984	4832	Inundated over 50000 km^2, estimated damage US$ 378 million
1987	4852	Inundated over 50000 km^2, estimated damage US$ 1 billion, 2055 deaths
1988	6146	Inundated 88000 km^2, estimated damage US$ 1.2 billion, more than 45 million homeless, between 2000-6500 deaths
1998	4618	Inundated nearly 100000 km^2, rendered 30 million people homeless, damaged 500000 homes, heavy loss to infrastructure, estimated damage US$ 2.8 billion, 1100 deaths
2004	4603	Inundation 55000 km^2, damage US$ 6.6 billion, affected nearly 3.8 million people. Estimated damage over $2 billion, 700 deaths
2007	not available	Inundated 32000 km^2, over 85000 houses destroyed and almost 1 million damaged, approximately 1.2 million acres of crops destroyed or partially damaged, estimated damage over $1 billion, 649 deaths

Source of flood record: Bangladesh climate change strategy and action plan (2008).

5. Concluding Remarks

The temporal characteristics of daily rainfall in the north-eastern part of Bangladesh have been studied by spectral analysis. The major outcome of the study is the prediction of major rainfall events which are prone for flood occurring. Temporal variation of monthly rainfall data was analyzed with the Fast Fourier Transform. Peak frequency of 0.084 month^{-1} is (11.98 months) observed from the spectra which means almost every year there is a peak rainfall event. The peak frequency is slightly less than 12 months indicating that major rainfall events are occurring earlier in a year compare to the previous year. The variability of rainfall pattern in time scale was also checked from filtered signals, which might be very useful for long-term water resources planning, agricultural development and disaster management for Bangladesh.

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