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Precipitation Distribution and Erosivity in Bangladesh: 1981-2010

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Abstract:

Erratic temporal distribution, highly intensive precipitation and rampant erosion are of major concern for Bangladesh in recent years. In this study attempts were taken to reveal the distribution of precipitation and erosion all over Bangladesh by means of two climate change related precipitation indices named Precipitation Concentration Index (PCI) and Modified Fournier Index (MFI). These indices were calculated by using monthly precipitation records from 18 observatory stations all over Bangladesh for the period of 1981-2010. Mann-Kendall trend test was executed to analyze the trend and Sen's slope method to determine the magnitude of changes for both indices. PCI values depict irregular distribution of precipitation all over the country and mostly negative changes. On the other hand MFI values indicate extreme erosion all through and mostly positive changes for the study period.

Key words: Bangladesh, Climate Change, Precipitation, Erosivity, Precipitation Concentration Index, Modified Fournier Index.

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Introduction

Rainfall is changing due to global warming on both the global [1,2,3] and the regional scales [4,5,6]. Future climate changes may involve modifications in climatic variability as well as changes in averages [7]. The implications of these changes are particularly significant for areas already under stress, such as in Bangladesh where hydrological disasters of one kind or another is a common phenomenon. Precipitation totals on annual, seasonal or monthly scales are key elements affecting water availability, but precipitation concentration in time also plays a decisive role. In this respect, there are some straightforward indicators to evaluate the precipitation concentration that can be used to provide information on its variability and to analyze and understand hydrological processes [8]. Different indices have been used for this purpose and among these the Precipitation Concentration Index (PCI) [9] is recommended, as it provides information on long-term total variability in the amount of rainfall received [8, 10, 11].

Different indices of rainfall aggressivity (erosivity) have been proposed for analyzing soil erosion, and the most appropriate ones seem to be those relating to soil erosion with kinetic energy of rainfall, such as the well-known EI_{30} [12]. However, there is scarce availability of high quality datasets on a regional scale, because EI_{30} requires rainfall data at intervals of one minute [13]. To avoid this problem, other indices based on monthly data averages have been proposed, such as Fourier Index (FI) and its modification by Arnoldus (1980) as Modified Fournier Index (MFI). Agreement between MFI with the USLE (Universal Soil Loss Equation) R factor (rainfall aggressivity factor) has been described on many occasions [13,14,15,16]and, as consequence, they are commonly used as the input aggressivity factor in the development of regional models [17]. This paper analyses the variability in space and time of PCI and MFI for the period of 1981-2010.

Data and Methodology

Figure 1(a) shows the position of Bangladesh (with latitude and longitude) which is basically the study area of this research. The total monthly precipitation data within the period of 1981-2010 are obtained from the 18 observatory stations (Figure 1b) of Bangladesh Meteorological Department (BMD).

Precipitation Concentration Index (PCI)

The Precipitation Concentration Index [9], proposed as an indicator of rainfall concentration and rainfall erosivity [10] can be calculated on an annual scale according to Equation (1):

$$PCI = \frac{\sum_{i=1}^{12} P_i^2}{(P_t)^2} * 100 \qquad \text{...(1)}$$

With P_i is the monthly precipitation in month i and P_t the annual precipitation.

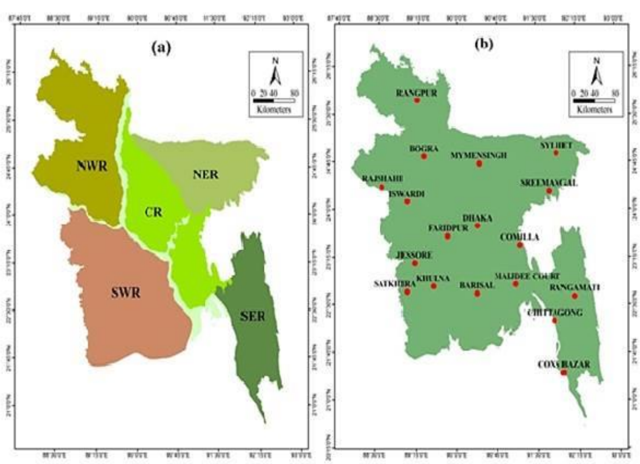

Figure1. (a) Study area with regions: Bangladesh (b) BMD stations

It was suggested that PCI values of 10 and below represent a uniform precipitation distribution (i.e., low precipitation concentration); PCI values above 10 to 15 denote amoderate irregularity of precipitation; values above 15 to 20 denote irregular distribution and values above 20 represent a strong irregularity (i.e., high precipitation concentration) of precipitation distribution[9]. PCI can have a maximum value of 100 when all the rainfall occurs in a month only. It has a minimum value of 8.3 when there is uniform rainfall in all months of the year.

Modified Fournier Index (MFI)

The Modified Fournier Index (MFI) [18,19]were calculated on an annual basis for each station, according to the following equation:

$$MFI = \sum_{i=1}^{12} \frac{P_i^2}{P_t} \qquad (2)$$

With P_i being the monthly precipitation at month i, and P_t the annual precipitation.

MFI value less than 60 indicates very low erosion capacity of rainfall; 60-90 indicates low,90-120 indicates moderate, 120-160 indicates high and value greater than 160 indicates very high erosion capacity of rainfall [20].

According to the available data sets two different procedures were followed to calculate (MFI) and (PCI):

- In the first procedure the (MFI) and (PCI) are calculated from the monthly rainfall amount of each individual year and averaged over. Those long term average values are reported as (MFI)1 and (PCI)1.
- In the second procedure the monthly rainfall amounts are averaged over the period. The (MFI) and (PCI) are then calculated from this averaged rainfall data set and reported as (MFI)2 and (PCI)2.

We have compared them for different regions and the relative value of them are same for all regions. The non-parametric Mann–Kendall trend test [21,22] is used to analyze the trends of indices. In the present study, confidence levels of 90% and 95% are taken as thresholds to classify the significance of positive and negative trends. The Sen's slope method [23] is used to detect the magnitude of changes. Mann-kendall trend test was executed and Sen's slope was calculated by using ProUCL4.1 software.

Results and Discussions

Modified Fournier index (MFI) in all stations and regions are well above 160 (Table 1) and according to the classification of CORINE (1992) [20] which indicates very high erosion power of precipitation. For South Eastern Region (SER) it is the highest and then comes North Eastern Region (NER), Central Region (CR), South Western Region (SWR) and North Western Region (NWR). So eastern region of the country is undergoing extreme erosion (Figure 2).

Both the (MFI)1 and (MFI)2 values shows the same relative values for different regions of Bangladesh (Figure 2).

In case of Precipitation Concentration Index (PCI) the hierarchy is quite different, although the highest value is in South Eastern Region (SER) like the MFI but the position of other regions change as NWR, SWR, CR and NER which is different from that of MFI pattern.

According to (PCI)1 all the country is experiencing irregular distribution of precipitation but (PCI)2 shows relatively lower values which is in the range of moderately irregular precipitation distribution according to Oliver,1980 (Table 1).

Regions	Stations	(PCI)1	(PCI)2	(MFI)1	(MFI)2
Central region(CR)	Dhaka	16.14	13.73	342.55	291.37
	Mymensingh	16.94	14.53	394.89	338.38
	Faridpur	16.78	14.32	337.89	287.09
	M. Court	17.16	14.11	377.21	306.98
	Comilla	16.73	13.92	348.54	291.86
North Western	Bogra	18.01	15.34	323.05	275.17

Region (NWR)	Rajshahi	17.98	15.49	264.25	226.24
	Rangpur	18.87	15.57	425.13	359.59
	Ishurdi	17.48	14.77	263.89	223.38
South Western Region (SWR)	Jessore	17.28	14.33	301.44	248.04
	Khulna	16.85	14.07	306.17	254.38
	Satkhira	16.75	14.39	293.78	252.49
	Barisal	17.26	14.42	363.29	302.49
South Eastern Regions (SER)	Chittagong	20.05	16.69	584.97	486.62
	Cox's bazar	19.64	17.76	733.96	661.53
	Rangamati	17.45	14.91	445.89	308.24
North Eastern Region (NER)	Sylhet	15.89	14.45	369.81	597.69
	Srimongol	16.12	13.77	665.81	317.77

Table 1. Average value of Annual PCI and MFI for the study period (1981-2010) in different BMD stations.

In calculation of (PCI)2 long term average of precipitation was used but for (PCI)1 individual year was considered. So (PCI)1 is more relevant than (PCI)2.According to this the country is under irregular distribution of precipitation.Both the (PCI)1 and (PCI)2 values shows the same relative values for different regions of Bangladesh(Figure 3).

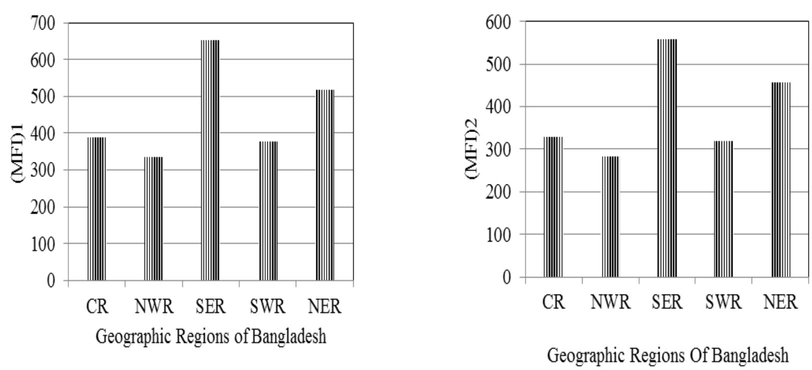

Figure 2: Average (MFI)1 and (MFI)2 values for different geographic regions of Bangladesh

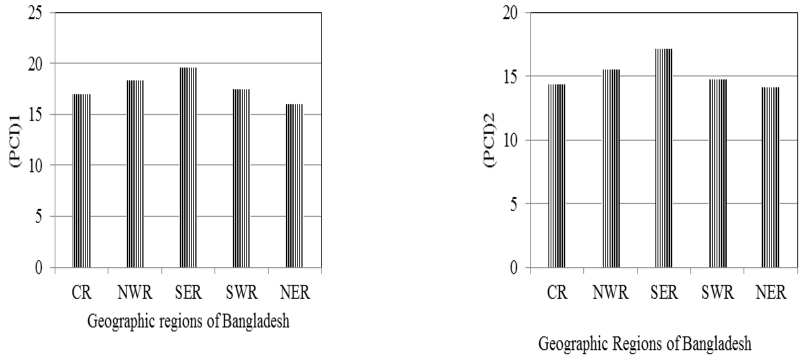

Figure 3: Average (PCI)1 and (PCI)2 values for different geographic regions of Bangladesh

Trends of Annual PCI and MFI in Table 2 shows positive trend in 4 stations and negative trend in 14 stations (statistically significant trend in 8 stations) for PCI and for MFI positive trend in 11 stations (statistically significant trend in 3 stations) and negative trend in 7 stations(statistically significant trend in 2 stations) is seen. So precipitation tends to be uniform and aggressive through the study period.

Regions	Stations	Trend	
		PCI	MFI
CR	Dhaka	+0.018	+0.221
	Comilla	+0.035	+1.528*
	Faridpur	-0.007	-1.375
	M. Court	-0.049	+0.654
	Mymensingh	-0.123**	-1.152
NER	Sylhet	-0.028	-1.512
	Srimongol	-0.081**	+0.409
NWR	Bogra	-0.064**	-0.719
	Ishurdi	-0.011	-1.894*
	Rajshahi	-0.033	-2.177**
	Rangpur	-0.070**	+0.9393
SER	Chittagong	-0.033	+1.142
	Cox's bazar	-0.059**	+2.942*
	Rangamati	-0.046**	+1.505
SWR	Barisal	+0.044	+0.416
	Jessore	+0.032	+2.025**

	Khulna	-0.072*	+0.840
	Satkhira	-0.071**	-0.740

Table 2.Trends of Annual PCI and MFI for the study period (1981-2010) in different BMD stations. The asterisk (**) denotes statistically significant trends at 95% confidence level and (*) denotes statistically significant figures at 90% confidence level.

Due to non-uniform precipitation there could be a long drought and vegetative cover will be lost. Reduced vegetation growth is followed by a net decrease of greenhouse gases assimilation by the plants and thus it may contribute to potential climate change at the local and regional scale and to desertification in a broad sense. Irregular and highly intensive precipitation is causing rampant erosion here and things might deteriorate in future. This is reducing the elevation over mean sea level. South eastern region and coastal region is of concern as the sea level is continually rising due to climate change. Due to erosion, silt charges in river water increases reducing its conveyance capacity as silts settle down to the river bed. This can cause longer lasting floods. Siltation is continually creating sandbar in rivers and diverts the flow of river. As a result river bank erosion occurs frequently.

Moreover due to sudden highly intensive rainfall water clogging would occur in cities due to the lack of drainage facilities. Bangladesh is a country which largely depends on its agriculture and hydroelectricity. So the findings of this study can also be useful for various applications in hydrology, ecology agriculture and also in policy making.

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