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Research paper

Trend analysis of rainfall data Rangpur, Bangladesh

Sudip Saha *

Department of Geology and Mining, University of Rajshahi, Rajshahi-6205, Bangladesh
**Corresponding author E-mail: sudips_geologist@yahoo.com*

Abstract

The study area lies in Bangladesh that is in the tropical area. The analysis of rainfall data reveals that the average annual rainfall in Rangpur was 2099.25 mm that varies from 427 mm to 3748 mm within the investigated period of time. The highest amount of annual rainfall was recorded in 1984. Heavy rainfall occurs in the month of July of the year. The highest amount of total monthly rainfall was recorded in July, 1987 and measured as 1314 mm. The rainfall trend can be expressed as monsoon rainfall > pre-monsoon rainfall> post monsoon rainfall. The total amount of annual rainfall is strongly significantly positively correlated with the total monthly rainfall of the months of June, July August, September and October and significantly positively correlated with the total monthly rainfall of the month April. The analysis shows that it rained in every year in the month of June as the minimum monthly value for June is greater than zero. Pearson correlation index shows that the mean daily temperature is significantly negatively correlated with daily rainfall which implies that fall of daily mean temperature with the daily rainfall. The increasing trend of annual rainfall suggests the climate change in Rangpur within the investigated period of time. In Rangpur, the value of skewness for all rainfall data are positive that indicate the data are skewed to the right. The positive values of kurtosis indicate that the distribution is not normal.

Keywords: *Annual Rainfall; Climate Change; Pearson; Monsoon and Rangpur.*

1. Introduction

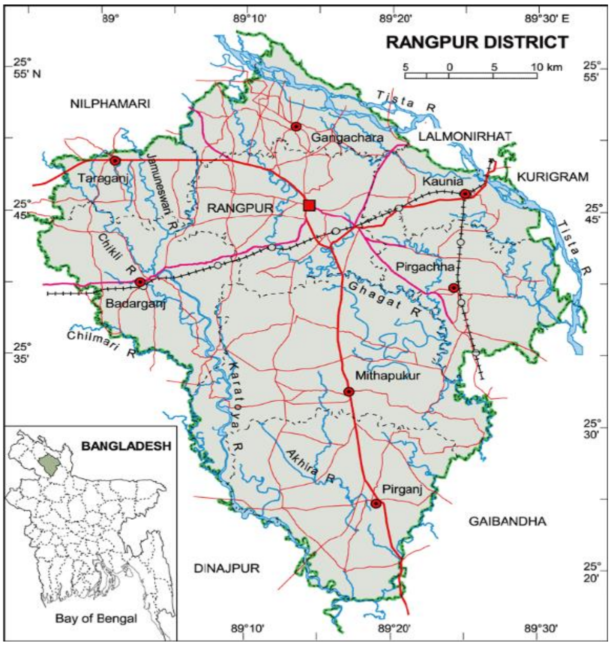

Fig. 1: Map of the Study Area, Rangpur, Bangladesh.

Rainfall is the major form of precipitation in Bangladesh. The rainfall is one of the principal factors that control the agriculture, health condition and life style of people of any region (Islam et al. 2019). Sometimes excess rainfall becomes curse for the people of Bangladesh. The study area Rangpur lies in the northern part of Bangladesh (Figure 1) and is characterized by heavy rainfall during the summer and low rainfall during pre-monsoon and post monsoon periods (Rahman et al. 2016). Rainfall is the main input of the hydrogeological cycle

of the study area. The climate change is measured by the rainfall patterns where Bangladesh is considered as one of the most vulnerable countries to climate change (IPCC 2007: Richard 2012).
The study area is drained by numerous rivers like Tista, Ghagat, Jamuneswari and Karatoa. It is the extension of the Himalayan piedmont plain that slope southward (Saha et al. 2020). The surface geology is mainly composed of gravel, sand, silt and clay of Recent age and in some areas by the clay deposits of Pleistocene age.
The present research work deciphers the total monthly rainfall and trend of annual rainfall. The annual rainfall is mainly influence by the monsoon wind. The daily rainfall also helps to lower the daily temperature especially in monsoon summer. The amount of annual rainfall shows positive correlation with time.

2. Methods

Daily rainfall data of Rangpur, Bangladesh was downloaded from website. From the daily rainfall data, total monthly rainfall was calculated using necessary computer software. The total annual rainfall was calculated by adding the total monthly rainfalls of twelve months of that specific year. The mean monthly rainfall and mean annual rainfall were analyzed. The required graphs were drawn. The Pearson correlation coefficients were calculated. The other statistical parameters such as mean, median standard deviation, skewness and kurtosis were calculated to analyze the yearly and monthly data (Islam et al. 2019). The daily rainfall data of the wettest month of July, 1987 were correlated with the mean daily temperature to show the influence of daily rainfall on daily mean temperature.

3. Results

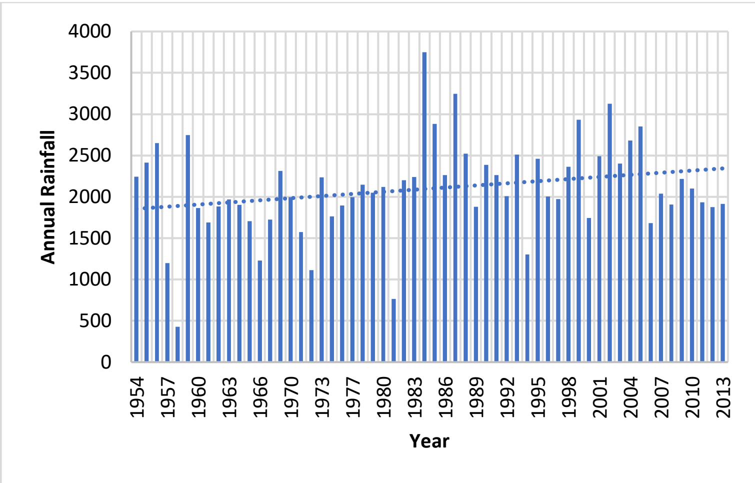

Fig. 2: Annual Trend of Rainfall in mm in Rangpur 1954-2013**.**

Figure 2: Shows The Distribution of Total Annual Rainfall of Rangpur Station During 1954-2013.The analysis of rainfall data reveals that the average annual rainfall in Rangpur during this period was 2099.25 mm. The highest amount of annual rainfall was recorded as 3748 mm in the year of 1984, while the lowest amount of annual rainfall was 427mm in the year of 1958. The total amount of annual rainfalls was higher than 3000mm in the years of 1984, 1987and 2002 in Rangpur (Figure 2). Figure 2 and Table 2 depict that the amount of total annual rainfall is positively correlated with time. The analyses of daily rainfall data reveal the maximum amount of daily rainfall was 294 mm in September 25, 2002. The heaviest rainfall in any given month during the study period was recorded in July, 1987.

Table 1: Statistical Summary of Monthly Rainfall Data of Rangpur

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean (mm)	8.45	9.14	27.36	92.17	263.47	440.55	447.1	328.24	309.83	158.84	7.64	7.21
Median (mm)	3	3.5	8.5	74.5	270.5	426.5	460	332.5	306.5	121	1	0
SD (mm)	11.35	13	42.72	76.73	102.29	190.14	219.27	187.99	178.83	144.96	17.14	17.17
Variance	128.7	169	1825.3	5887.7	10464	36154.6	48080.4	35338.5	31979.6	21014.1	293.9	294.8
Skewness	1.63	1.89	3.3	1.27	0.02	0.8	0.99	0.49	0.53	1.36	4.21	3.68
Kurtosis	2.44	3.42	14.52	2.27	0.34	1.15	3.28	0.21	0.05	1.4	21.74	16.91
Max (mm)	49	57	257	376	545	989	1314	832	804	586	109	103
Min (mm)	0	0	0	0	0	104	0	0	0	0	0	0
Range (mm)	49	57	257	376	545	885	1314	832	804	586	109	103
Sum (mm)	490	530	1587	5346	15281	25552	25932	19038	17970	9213	443	418

Table 1 shows the distribution of mean monthly rainfall of Rangpur station during 1954-2013. Figure 3 shows that 80.21% annual rainfall occurs during the monsoon months of June-October, while 18.67% annual rainfall occurs in the pre-monsoon months of February-May and 1.11% annual rainfall was recorded in post monsoon periods November-January.

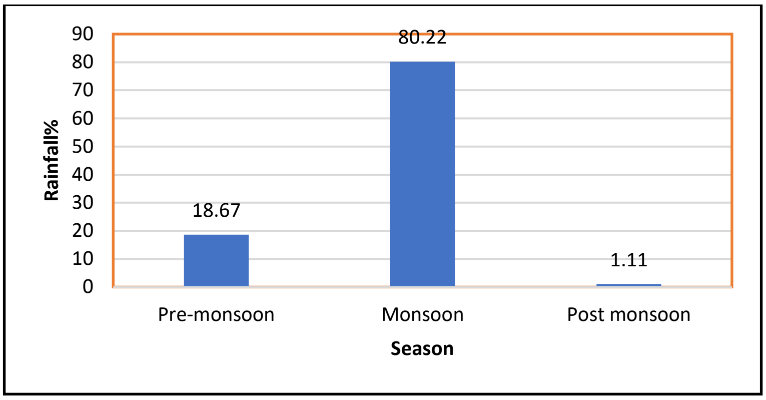

Fig. 3: Distribution of Rainfall in Different Seasons.

Table 2: Detailed Statistical Summary of Annual Rainfall Data of Rangpur

Year	Annual (mm)	Mean (mm)	Median (mm)	SD (mm)	Variance (mm)	Skewness	Kurtosis	Max. (mm)	Min. (mm)	Range (mm)
1954	2243	186.9	55.0	297.4	88466.6	1.9	3.3	944	0	944
1955	2414	201.2	37.5	300.2	90100.7	1.5	1.2	892	0	892
1956	2650	220.8	80.5	265.4	70454.0	0.9	-0.4	769	0	769
1957	1199	99.9	5.0	157.4	24790.1	1.4	0.7	439	0	439
1958	427	35.6	0.0	69.1	4776.4	1.9	2.1	188	0	188
1959	2748	229.0	180.0	210.4	44275.1	0.7	-0.8	586	0	586
1960	1864	155.3	73.5	190.7	36355.9	0.9	-0.8	488	0	488
1961	1717	143.1	99.0	153.4	23528.4	0.8	-0.7	440	0	440
1962	1882	156.8	37.5	209.3	43817.1	1.1	-0.3	572	0	572
1963	1967	163.9	73.5	187.2	35050.6	1.1	0.2	566	0	566
1964	1902	158.5	104.0	190.9	36453.9	1.2	0.5	554	0	554
1965	1708	142.3	50.5	179.9	32366.2	1.3	0.9	553	0	553
1966	1231	102.6	36.5	126.1	15894.3	1.0	-0.7	324	0	324
1967	1723	143.6	144.5	148.7	22119.9	1.1	0.8	474	0	474
1969	2313	192.8	71.5	212.7	45256.4	0.9	-0.3	636	0	636
1970	1997	166.4	39.0	209.1	43707.4	1.0	-0.8	527	0	527
1971	1573	131.1	30.5	169.6	28777.5	0.9	-0.8	438	0	438
1972	1114	92.8	47.5	108.4	11746.0	1.1	0.3	325	0	325
1973	2237	186.4	58.5	246.4	60727.0	1.4	1.0	744	4	740
1975	1763	146.9	119.5	170.3	28998.3	1.0	-0.1	468	0	468
1976	1895	157.9	85.0	192.0	36855.0	0.9	-0.8	500	0	500
1977	1996	166.3	120.5	187.3	35080.1	0.9	-0.3	550	0	550
1978	2145	178.8	105.0	204.9	41998.9	0.8	-0.9	530	0	530
1979	2048	170.7	87.5	220.3	48542.6	1.5	1.5	677	0	677
1980	2120	176.7	53.0	205.8	42366.6	0.8	-0.8	579	0	579
1981	763	63.6	11.5	124.5	15506.6	2.8	8.1	432	0	432
1982	2201	183.4	81.5	232.1	53876.1	1.0	-0.5	649	0	649
1983	2238	186.5	152.0	198.8	39505.9	1.0	0.7	636	0	636
1984	3748	312.3	144.0	358.9	128841.0	0.8	-0.8	989	0	989
1985	2882	240.2	182.0	250.8	62921.2	0.9	0.1	770	0	770
1986	2264	188.7	151.0	189.2	35809.0	0.5	-1.2	518	0	518
1987	3247	270.6	119.5	381.3	145410.6	2.1	5.0	1314	0	1314
1988	2524	210.3	101.0	227.2	51625.5	0.7	-1.0	633	0	633
1989	1878	156.5	33.0	227.5	51767.0	1.7	2.4	719	0	719
1990	2386	198.8	179.0	172.3	29693.4	0.1	-1.8	439	0	439
1991	2263	188.6	73.5	243.9	59472.8	1.4	1.1	726	1	725
1992	2007	167.3	109.0	183.7	33746.0	0.9	-0.1	552	0	552
1993	2510	209.2	76.5	239.7	57475.6	0.9	-1.0	633	0	633
1994	1301	108.4	73.0	124.4	15470.8	1.7	3.2	427	0	427
1995	2461	205.1	80.0	268.1	71865.9	1.3	0.8	804	1	803
1996	2004	167.0	99.0	182.9	33443.8	0.5	-1.5	479	0	479
1997	1971	164.3	70.0	184.8	34139.7	0.8	-0.7	523	2	521
1998	2365	197.1	187.5	186.8	34905.7	0.3	-1.6	473	0	473
1999	2931	244.3	265.5	257.9	66510.9	0.9	0.8	829	0	829
2000	1745	145.4	92.5	165.9	27527.0	0.8	-0.8	438	0	438
2001	2492	207.7	136.5	219.6	48227.3	0.4	-1.7	550	0	550
2002	3127	260.6	193.0	293.6	86193.5	1.1	0.6	913	0	913
2003	2402	200.2	151.5	213.0	45349.2	1.2	0.5	633	0	633
2004	2680	223.3	164.5	229.5	52677.9	0.6	-1.0	653	0	653
2005	2853	237.8	182.0	242.4	58752.9	0.6	-1.1	671	0	671
2006	1682	140.2	90.5	160.1	25628.5	1.0	0.0	472	0	472
2007	2037	169.8	92.5	205.5	42236.4	1.3	0.5	568	0	568
2008	1907	158.9	124.5	156.8	24598.1	0.6	-0.8	444	0	444
2009	2217	184.8	117.5	242.2	58652.8	1.9	4.3	832	0	832
2010	2102	175.2	145.5	200.3	40134.0	1.2	1.5	650	0	650
2011	1932	161.0	24.0	198.0	39194.2	0.8	-1.0	542	0	542
2012	1877	156.4	122.0	171.7	29483.4	0.6	-1.2	445	0	445
2013	1916	159.7	172.0	151.2	22855.9	0.1	-1.9	383	0	383

January: The mean monthly rainfall for the month of January is 8.45 mm in the study area, while the total rainfall varies from 0 mm to 49 mm (Figure 4). It did not rain 22 years in the month of January in Rangpur. The mean monthly rainfall has a decreasing trend with time (years).

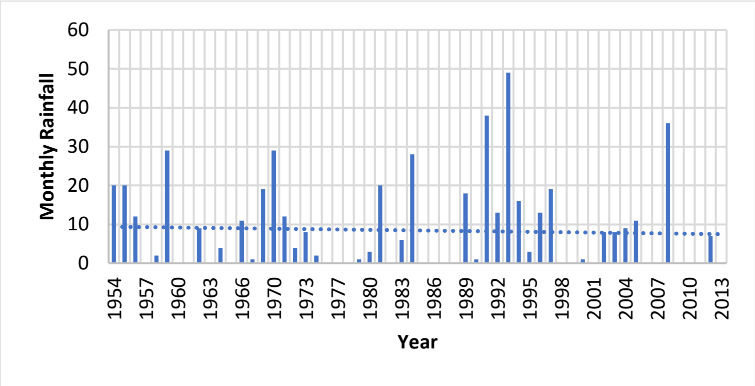

Fig. 4: January Rainfall in mm in Rangpur 1954-2013.

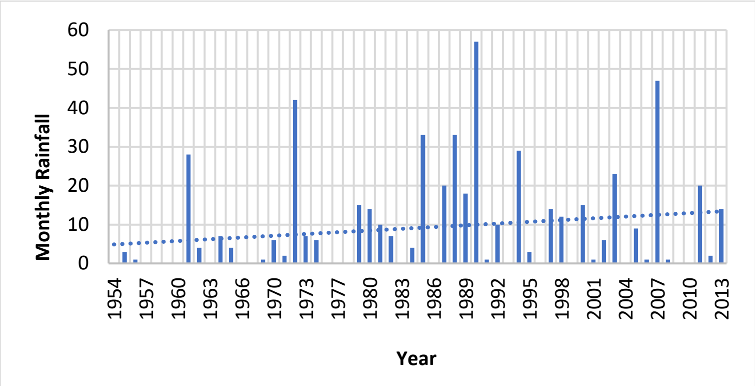

Fig. 5: February Rainfall in mm in Rangpur 1954-2013.

February: The total amount of rainfall varies from 0 mm to 57 mm for the month of February (Figure 5). The mean monthly rainfall for the month of February is 9.145 mm in the study area, while it did not rain 19 years in the month of February in Rangpur. The mean monthly rainfall of this month is increasing with time (years).

March: The total amount of rainfall during the month of March was highest in 1959 that was recorded as 257 mm (Figure 6). There was no rainfall during the month of March in seven years like 1954, 1957, 1971, 1977, 1992, 1996 and 2010. The total monthly rainfall for the month of March is negatively correlated with time. The mean monthly rainfall of March is 27.36 mm.

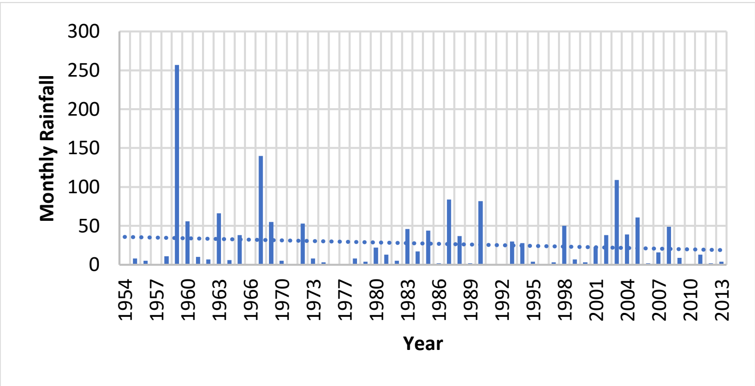

Fig. 6: March Rainfall in mm in Rangpur 1954-2013.

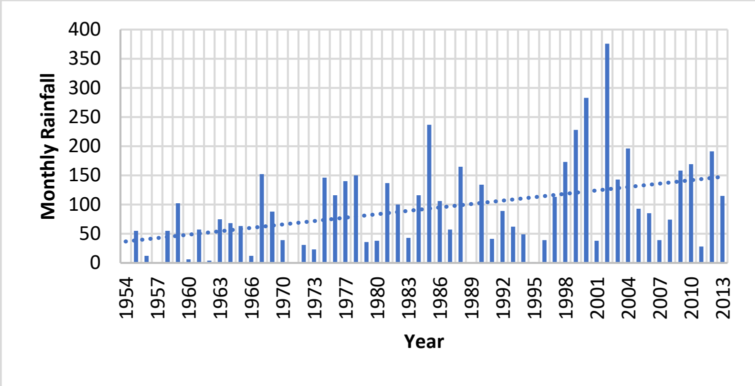

Fig. 7: April Rainfall in mm in Rangpur 1954-2013.

April: The amount of rainfall in the month of April starts to increase that is resulted by the higher amount of evaporations from the Bay of Bengal. Highest amount of total rainfall in the month of April was reported from the year 2002 whose numerical value was 376 mm. The mean monthly value for the month of April was 92.17 mm. There was no rainfall in April for the years of 1954, 1957, 1971 and 1989. The amount of rainfall is positively correlated with time (Figure 7).

May: The maximum amount of rainfall of May was 545 mm which was recorded in 1984. The average value of rainfall of May is 263.46 mm. The median value of rainfall is 270 mm. The amount of rainfall is always higher than 70 mm except that of 1971. The magnitude of rainfall slightly increasing in expense of time (Figure 8). The increased amount of May rainfall might have influence by the increased amount of evaporation from the irrigated farmland in the study area.

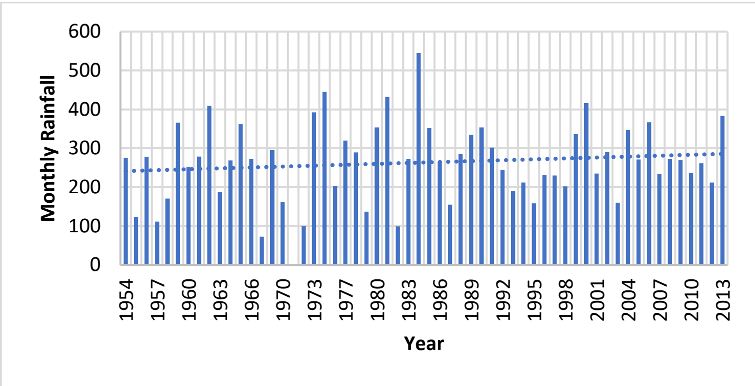

Fig. 8: May Rainfall in mm in Rangpur 1954-2013.

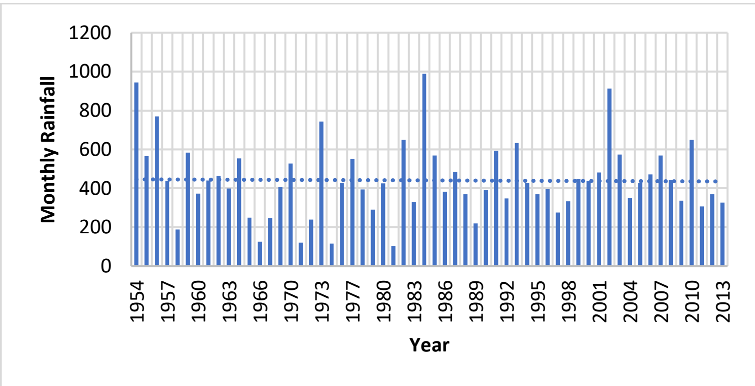

Fig. 9: June Rainfall in mm in Rangpur 1954-2013.

June: The amount of June rainfall varies from 104 mm to 989 mm with the mean rainfall value of 440.55 mm. The median value for the June rainfall is 426.5 mm. The distribution of total amount of rainfall remained even for the investigated time period in Rangpur (Figure 9). The maximum amount of June rainfall was reported in the year of 1984.

July: July is the wettest month of the year. The total amount of July rainfall remained more or less uniform over time (Figure 10). It did not rain only two years (1958 and 1981) in the month of July. The median July rainfall value is 460 mm (Table 1). The average magnitude is 447.10 mm while the highest amount of July rainfall was 1314 mm in the year of 1987.

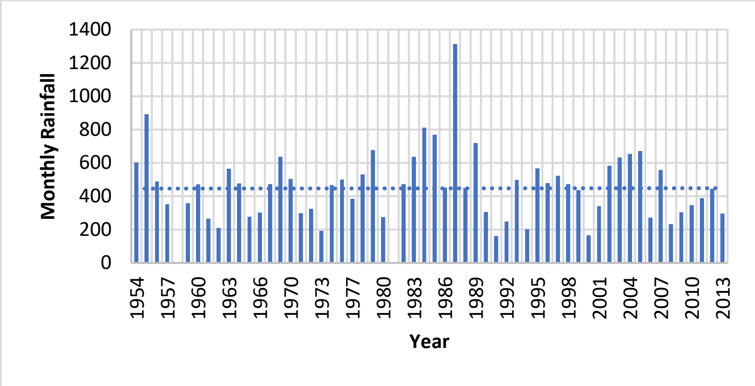

Fig. 10: July Rainfall in mm in Rangpur 1954-2013.

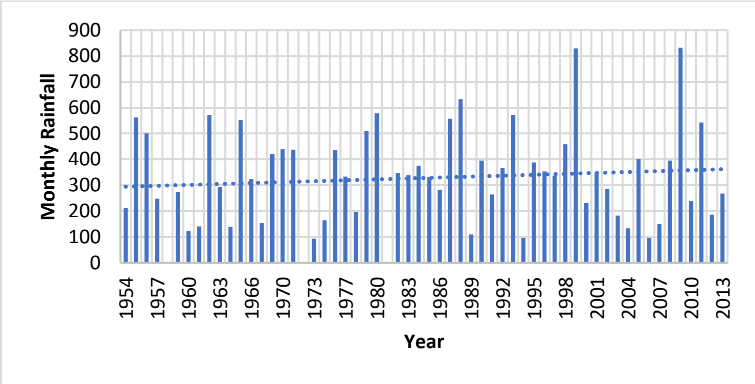

Fig. 11: August Rainfall in mm in Rangpur 1954-2013.

August: The maximum amount of August rainfall was 832 mm in the year of 2009 and lowest rainfall was 94 mm in 1973 (Figure 11). The amount of rainfall starts to decrease in August. The mean rainfall for the month of August was 328.24 mm while the median value is 332.5mm. The August rainfall is positively correlated with time.

September: The median value of September rainfall is 306.5 mm while the mean value is 309.83 mm. The magnitude of September rainfall is increasing in expense of time (Figure 12). The maximum September rainfall was 804 mm in 1995 while least amount of rainfall was 38 mm in 1957.

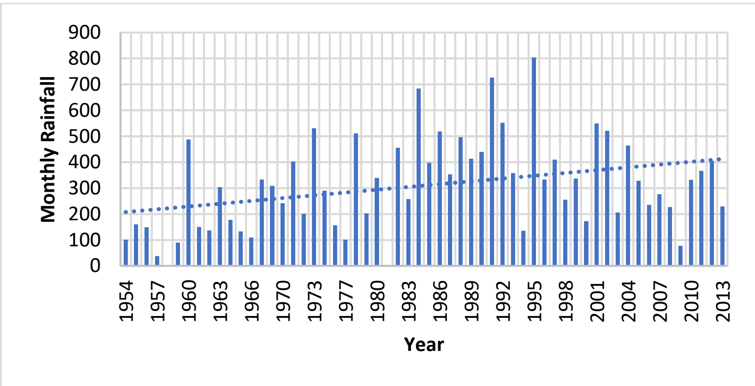

Fig. 12: September Rainfall in mm in Rangpur 1954-2013.

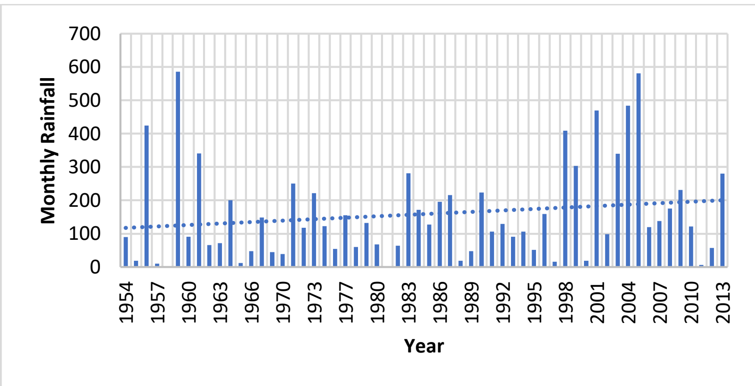

Fig. 13: October Rainfall in mm in Rangpur 1954-2013.

October: The frequency of October rainfall is significantly marked by the decrease of mean value. The total amount of October rainfall varies from 6 mm (2011) to maximum 586 mm in 1959. The average value of October rainfall was 158.84 mm and the median value was 121 mm. The amount of October rainfall is positively correlated with time (Figure 13).
November: The mean rainfall value of November was 7.64 mm. The median was 1 mm. The maximum amount of rainfall in November was 109 mm in 1995 while there was no rainfall in 27 years (Figure 14). The rainfall pattern was almost steady over the period of investigation in Rangpur.

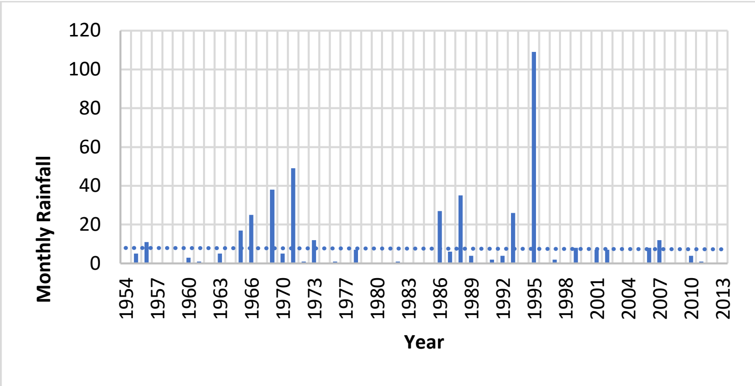

Fig. 14: November Rainfall in mm in Rangpur 1954-2013.

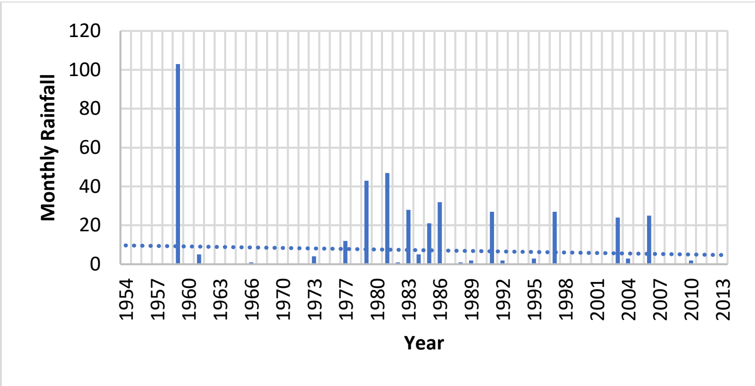

Fig. 15: December Rainfall in mm in Rangpur 1954-2013

December: The median value of December rainfall was 0 mm whereas the mean rainfall was 7.21mm. There was no rainfall in 36 years in the month of December. The maximum amount of rainfall was recorded in the year of 1959 which was 103 mm. The pattern of December rainfall is decreasing with time (Figure 15).
Statistical Analysis of Rainfall
Table 1 shows the results of statistical analyses of rainfall data in millimeters. The amount of rainfall starts to increase from the month of March, reaches to the peak in July and then begins to fall. The highest total monthly rainfall was recorded in July 1987 that was 1314 mm. Most of the rainfall occur in the months of May, June, July, August, September and October. The analysis shows that it rained in every year in the month of June as the minimum monthly value for June is greater than zero. The standard deviation and range describe the variability of annual rainfall and signify how reliable the rainfall in terms of its persistence as constant and stable replenishing source (Islam 2019). A high standard deviation value means that the rainfall is spread wide on the either sides of the mean.
Skewness and kurtosis were computed to test the pattern of annual rainfall data. The skewness for a normal distribution is zero, and any symmetrical data should have skewness value close to zero. Negative skewness values indicate that the data are skewed to the left while the positive skewness values suggest that the data are skewed to the right. In Rangpur, the value of skewness for all rainfall data are positive that indicate the data are skewed to the right.
Kurtosis is a measure of peakedness or flatness to normal distribution. The positive value of kurtosis means a peaked distribution and a negative value reveals the flat distribution with the same mean and standard deviation. The annual rainfall distribution under this circumstance, did not follow the normal distribution.

4. Discussion

The rainfall varies in different months of the year. The amount of rainfall influences the agricultural activities of a region. The analysis of rainfall data is important for proper crop management. The rainfall also controls the hydrogeological characters of an area. In Rangpur region, the water from the rainfall recharge the groundwater aquifer, surface water bodies and the quality of groundwater and surface water bodies depends on the recharge and discharge of them. The aquifers of Rangpur have the highest transmissivity in Bangladesh that vary from 1000-7000 square meters/day (UNDP 1982: Hussain and Abdullah 2001: Saha et al. 2019)).

Table 3: Pearson Correlation Coefficient Matrix of Total Monthly Rainfall and Total Annual Rainfall (N=58)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Octo	Nov	Dec	Total
Jan	1.000												
Feb	-0.218	1.000											
Mar	0.116	0.127	1.000										
Apr	-0.200	0.056	0.135	1.000									
May	0.083	0.015	-0.042	0.280*	1.000								
Jun	0.271*	-0.080	0.032	0.138	0.182	1.000							
Jul	-0.004	0.050	0.173	0.051	-0.179	0.282*	1.000						
Aug	0.033	-0.112	-0.053	0.037	-0.042	0.073	0.239	1.000					
Sep	0.071	0.017	-0.084	0.100	0.051	0.200	0.249	0.051	1.000				
Octo	-0.008	-0.023	0.451**	0.083	0.087	0.152	0.128	0.053	0.019	1.000			
Nov	0.019	-0.098	-0.113	-0.207	-0.221	-0.120	0.064	0.184	0.403**	-0.142	1.000		
Dec	0.236	-0.058	0.507**	0.044	0.179	-0.010	-0.064	-0.147	-0.131	0.272*	-0.093	1.000	
Total	0.140	-0.013	0.251	0.318*	0.230	0.620**	0.656**	0.469**	0.524**	0.440**	0.085	0.058	1.000

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

The total amount of annual rainfall is strongly significantly positively correlated with the total monthly rainfall of the months of June, July August, September and October and significantly positively correlated with the total monthly rainfall of the month April (Table 3). This study reveals that the total annual rainfall is mainly influenced by the total amount of monsoon rainfall. The heavy rainfall in May-September is suggestive that the study area is located in humid tropical area and the rainfall is influenced by the South West Monsoon. The amount of pre-monsoon rainfall also influences the total annual rainfall of Rangpur. On an average 18.67% rainfall of the year occurs in Pre-monsoon periods. The importance of pre-monsoon period is increasing day by day with the increased cultivation of rice in this time span. The Pearson correlation matrix index of daily rainfall and mean daily temperature (of July, 1987) shows that they are significantly negatively correlated. This result suggests that the daily temperature in Rangpur during the summer monsoon is controlled by the amount of rainfall.

5. Conclusion

The trend of annual rainfall is increasing and the mean annual rainfall is 2099.25 mm. The maximum amount of rainfall is recorded during the summer monsoon. The total annual rainfall is significantly positively correlated with the monsoon rainfall. The analysis shows that it rained in every year in the month of June as the minimum monthly value for June is greater than zero. The climate change can be revealed by the increment of pre-monsoon rainfall especially in the month of May. May is the harvesting time of paddy in Rangpur. The heavy rainfall in May might have impact on the production of rice. The daily temperature in the summer months lowered by the amount of daily rainfall in those months. In Rangpur, the value of skewness for all rainfall data are positive that indicate the data are skewed to the right. The positive values of kurtosis indicate that the distribution is not normal. Further research works can be taken on the seasonal variability of chemical composition of ground and surface waters and the change in groundwater levels.

6. Conflict of interest statement

Author does not have any conflicts of interest.

Acknowledgement

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