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551.577.3 : 551.553.21 : 551.515.1 (549.3)

Rainfall distribution over Bangladesh stations during the monsoon months in the absence of depressions and cyclonic storms

M. AMIRUL HUSSAIN and NAHID SULTANA
Bangladesh Meteorological Department, Dhaka
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सार — मानसून वर्षा की बंगलादेश के वार्षिक वर्षा वितरण में महत्वपूर्ण भूमिका है। सामान्यत: यह माना जाता है कि मानसून के महीनों में मानसून अवदाब और चक्रवातीय तूफान बंगलादेश के वर्षा वितरण को उल्लेखनीय रूप से प्रभावित करते हैं तथा जिस महीने में ये नहीं होते हैं उस महीने में कम वर्षा होती है। इस तथ्य की जांच 1948-91 की अवधि में, जिन मानसून महीनों में मानसून अवदाब नहीं बने तथा चक्रवातीय तूफान भी नहीं आए, उन महीनों की बंगलादेश के मौसम विज्ञान विभाग द्वारा वहां की 32 वेधशालाओं की औसत वर्षा के किए गए आकलन के आधार पर की गई है। यह पाया गया है कि देश के विभिन्न केन्द्रों में अलग-अलग मानसून महीनों में कम वर्षा तथा उसके फलस्वरूप सूखे की स्थिति का मुख्य कारण चक्रवातीय तूफान तथा मानसून अवदाब की अनुपस्थिति नहीं है। मानसून (जून-सितम्बर) के दौरान चक्रवातीय तूफानों और अवदाबों की अनुपस्थिति के बावजूद देश के सभी केन्द्रों में वर्षा की स्थिति सामान्य रही।

ABSTRACT. Monsoonal rainfull plays an important role in the annual rainfall distribution over Bangladesh. It is generally believed that monsoon depressions and cyclonic storms significantly affect the rainfall distribution over Bangladesh during the monsoon months and their absence causes deficient rainfall during the individual monsoon months. This aspect has been examined by computing the average rainfall for 32 meteorological observatories of Bangladesh Meteorological Department during the period 1948-91 for those monsoon months which were free from depressions and cyclonic storms. It has been found that the absence of monsoon depressions and cyclonic storms is not the main factor which causes deficient rainfall and consequest drought conditions in the individual monsoon months over different stations of the country. All the stations in the country experienced normal rainfall conditions inspite of the absence of depressions and cyclonic storms in the monsoon season (June-September).

Key words — Monsoon, Rainfall, Drought condition, Cyclonic circulations, Orography, Departures of rainfall.

1. Introduction

It is generally felt that monsoon depressions and cyclonic storms are the most important synoptic scale disturbances and play a vital role in the space-time distribution of rainfall over Bangladesh. In the present paper an attempt has been made to study the behaviour of rainfall distribution at individual stations during the absence of these disturbances in the individual monsoon months and the monsoon season as a whole. This paper also includes the study of rainfall distribution over Bangladesh during monsoon months of June to September separately and monsoon season as a whole.

2. Data

Rainfall data for 32 stations during the period 1948-91 was collected from Climate Division, Bangladesh Meteorological Department (BMD). The data of cyclonic storms, depressions, well-marked lows, onset and withdrawal dates of monsoon etc. were collected from the Storm Warning Centre, BMD using Bangladesh daily weather summaries, special weather bulletins, warning action books and accounts of depressions and storms in the Bay of Bengal during the period 1948-91. The individual monsoon months, when no depression and cyclonic storms affected the Bangladesh land area, were included in this study. This examination shows that during the 44-year period (1948-91) there were in all 31 June, 42 July, 36 August and 37 September months when the Bangladesh land area was completely free from these disturbances. Table 1 shows the individual monsoon months which were free from these disturbances during the period 1948-91.

Mear monthly values of rainfall data of 32 observat ories of BMD were calculated during the period 1 48-91 for the months of June to September separately and monsoon season as a whole and maps were prepared and analysed. Isolines on these maps are drawn at intervals of 50 to 200 mm and presented in Figs. 1 (a-d) & Fig. 2. These mean values of 44-year data of individual monsoon months and monsoon season are treated as normal values. Using the following drought classification

TABLE 1

Monsoon months when the Bangladesh land area did not experience depressions and cyclonic storms during the period 1948 to 1991

June		July		August		September	
1948	1973	1948	1971	1948	1976	1948	1974
1949	1974	1949	1972	1949	1977	1949	1975
1951	1976	1950	1973	1950	1978	1950	1977
1952	1977	1952	1974	1951	1980	1951	1979
1953	1978	1953	1975	1952	1981	1952	1980
1954	1980	1954	1976	1953	1982	1953	1981
1955	1981	1955	1977	1954	1983	1954	1982
1958	1983	1956	1978	1956	1984	1955	1983
1959	1984	1957	1979	1958	1985	1956	1984
1960	1985	1958	1980	1959	1986	1958	1985
1962	1986	1959	1981	1961	1987	1959	1986
1964	1988	1960	1982	1962	1988	1960	1987
1967	1989	1961	1983	1963	1989	1961	1988
1968	1990	1962	1984	1965	1990	1963	1989
1970		1963	1985	1966	1991	1964	1990
1971		1964	1986	1967		1965	1991
1972		1966	1987	1968		1967	
		1967	1988	1970		1968	
		1968	1989	1971		1970	
		1969	1990	1973		1972	
		1970	1991	1975		1973	
Total	31		42		36		37

based on rainfall given by Krishna Rao (1953) and used by Dhar *et al.* (1976, 1980, 1984), monthly percentage departures of rainfall for the individual monsoon months and monsoon season for 32 stations of Bangladesh were calculated and presented in Table 2.

Drought Classification based on rainfall	*Percentage departures from the normals*
(*i*) Excess rainfall	+11% or more
(*ii*) Normal rainfall	+10% to −10%
(*iii*) Slight drought	−11% to −25%
(*iv*) Moderate drought	−26% to −40%
(*v*) Severe drought	−41% and less.

The highest and lowest percentage departures of rainfall from the normals for 32 stations of BMD for each of the monsoon months, which were free from these disturbances, were calculated, analysed and presented in Table 3.

3. Results and discussion

From the 44-year normal rainfall distribution maps [Figs. 1 (a-d) & Fig. 2], monthly percentage departures of rainfall from the normals for the individual monsoon months and monsoon season (Table 2) and the highest and lowest percentage departures of rainfall from the normals for individual stations and monsoon months (Table 3), the principal monthly and monsoon season features were studied and the findings are mentioned below:

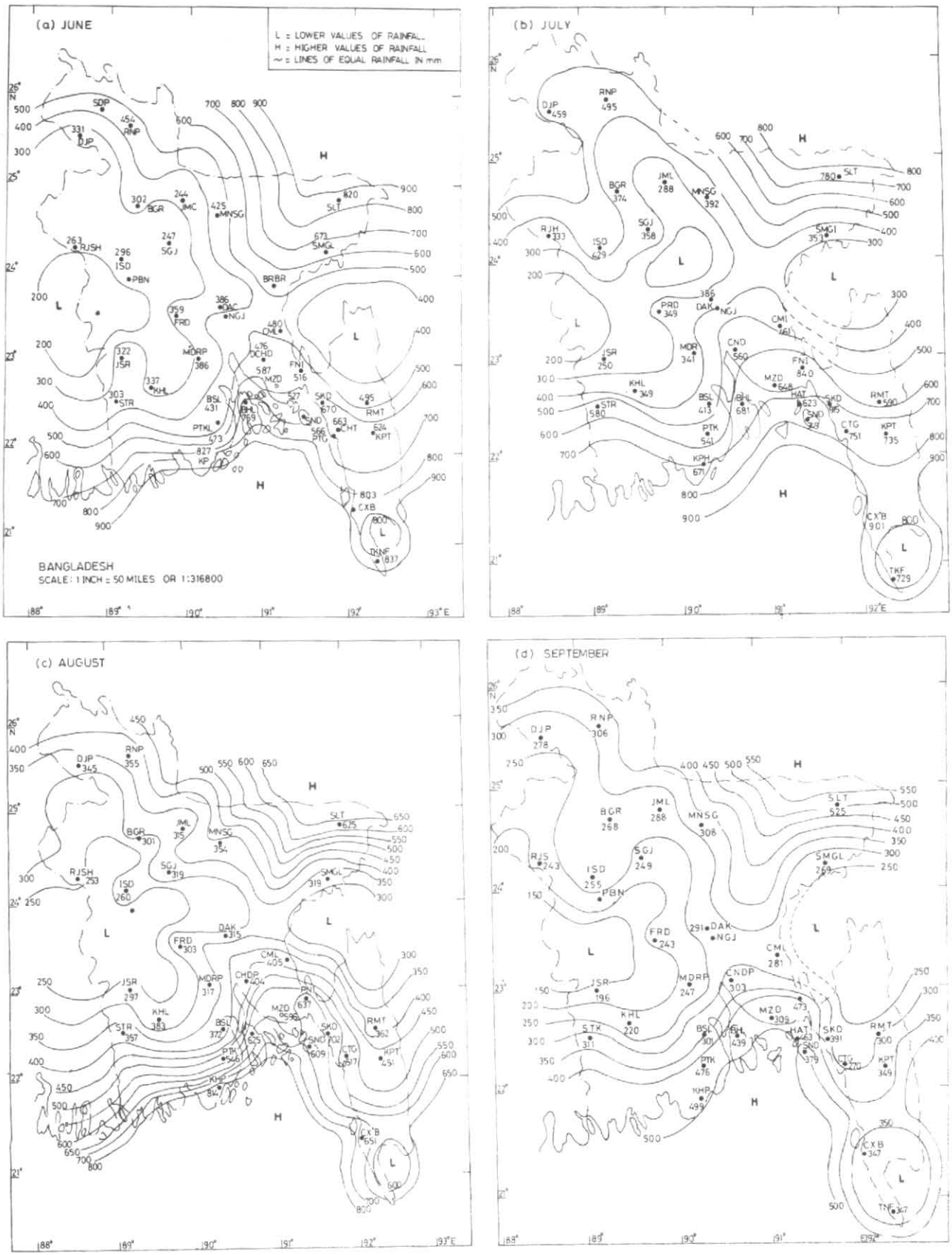
3.1. *June*

From the 44-year normal rainfall distribution map for the month of June during the period 1948-91 [Fig. 1 (a)], it is observed that the highest rainfall

TABLE 2

Percentage departures of rainfall for different stations during individual monsoon months and monsoon season which did not experience depressions and cyclonic storms during the period 1948 to 1991

Stations	June (%)	July (%)	August (%)	September (%)	Monsoon season (June-Sept) (%)
Barisal	+6.03	+1.69	−5.38	−1.33	+0.59
Bhola	−2.86	±0.00	+6.72	+3.23	+1.35
Bogra	+15.56	−1.34	+1.99	+1.87	+4.25
Chandpur	+9.15	+2.68	+3.22	+7.92	+5.64
Chittagong	−7.24	−0.53	+5.61	+0.37	−0.91
Comilla	+1.25	−3.04	+0.25	+2.85	+0.12
Cox's Bazar	+0.62	−0.22	−5.53	+2.02	−0.92
Dhaka	−10.88	−2.07	−2.86	+1.72	−3.77
Dinajpur	+13.60	+3.70	+1.16	+2.88	+5.30
Faridpur	+4.74	+2.29	+0.99	+3.70	+2.95
Feni	−9.11	±0.00	−1.57	+3.59	−1.62
Hatiya	+8.35	±0.00	−7.13	+0.22	+0.22
Ishurdi	+22.97	−2.63	−8.85	+3.53	+3.65
Jamalpur	−18.00	−7.68	+11.18	+3.23	−1.98
Jessore	−4.66	+0.67	+2.02	−0.51	+3.75
Kaptai	−7.37	−0.95	−2.66	+2.87	−2.55
Khepupara	−13.30	±0.00	+1.97	+5.01	−2.42
Khulna	+8.01	−0.29	+6.36	+9.09	+5.38
Madaripur	−0.59	±0.00	±0.00	+0.00	−1.50
Maijdi court	+4.77	−0.46	+18.12	+4.34	+6.81
Mymensingh	+13.18	−0.51	+3.39	+9.74	+6.69
Patuakhali	+6.77	±0.00	±0.00	+6.93	+3.19
Rajshahi	+30.51	−1.20	−1.58	−2.06	+5.40
Rangpur	+5.29	+1.41	+7.32	+5.56	+4.65
Rangamati	+4.04	−0.34	−3.31	−3.33	−0.17
Sandwip	+8.13	±0.00	−5.58	−5.28	−0.30
Satkhira	−15.84	+2.59	+5.32	+0.96	−0.65
Serajgonj	−12.23	+1.99	+9.39	+5.48	+1.57
Sitakunda	+17.46	±0.00	±0.00	±0.00	+4.30
Srimangal	−23.63	±0.00	+1.57	+4.09	−8.67
Sylhet	+8.90	+1.03	+2.08	+11.43	+5.67
Teknaf	+0.72	±0.00	±0.00	±0.00	+0.23



Figs. 1 (a-d). Rainfall (mm) distribution (1948-91) in (a) June, (b) July, (c) August and (d) September

are 837 and 803 mm at Taknaf and Cox's Bazar respectively in the southeastern side and another highest value is 820 mm at Sylhet in the northeastern side and the lowest rainfall is 263 mm at Rajshahi in the northwestern side of the country. Thus, northeastern, southeastern and southern parts of Bangladesh are high rainfall area and western and northwestern parts of Bangladesh are low rainfall area.

During the 44-year period there were in all 49 disturbances originating in the Bay of Bengal out of which only 13 disturbances traversed over the Bangladesh land area in this month.

Percentage departures of rainfall from the normal [Fig. 1 (a)] for 32 stations were calculated for each of the June months which were free from depressions and cyclonic storms as in Table 1 and presented in Table 2. From Table 2, it has been observed that in June, Mymensingh, Dinajpur, Bogra, Rajshahi, Ishurdi, Sitakunda experienced excess rainfall (+13.18% to +30.51%); Dhaka, Khepupara, Satkhira, Srimangal, Jamalpur, Serajganj experienced slight drought conditions (−10.88% to −23.63%) and rest of the stations of the country experienced normal rainfall (+9.15% to −9.11%). The southwest monsoon, normally strikes the southeastern tip, *i.e.*, Cox's Bazar by 2nd June and then advances northwestwards and completly sets in over the whole country by June 15 (Ahmed and Karmakar 1993). However, it is seen that the onset of southwest monsoon either gets delayed or sets in early by a few days from the normal date of onset. Even though monsoon may set in by the normal date in a particular year but the monsoon may fail to establish over the whole country with the result that weak monsoon conditions prevail over the country in this month.

From the lowest percentage departures of rainfall from the normals as shown in Table 3, it has been observed that different stations of the country experienced severe drought conditions (−48.45% to −98.51%) in the June months of the years 1958, 1967, 1970, 1971, 1980, 1981, 1983, 1984, 1985, 1986 and 1989. The value of the highest percentage of departure from normal is −48.45% at Madaripur (1986) and the lowest value is −98.51% at Chandpur (1985). Drought conditions in the June months of the years mentioned above are due to the delayed onset of monsoon, weak monsoon conditions prevailing over the country, absence of pre-monsoon thunderstorm activities over northern and central parts of the country and the non-occurence of lows or well marked low pressure areas. Thus, in the June month drought conditions may prevail over the different stations of the country in the absence of these disturbances if the above mentioned unfavourable meteorological situations are present.

From the highest percentage departures of rainfall from the normals as shown in Table 3, it has also been observed that the different stations of the country experienced excess rainfall (+16.24% to +542.13%) in the June months of the years 1951, 1954, 1964, 1968, 1973, 1976, 1977, 1978, 1981, 1983, 1984, 1985, 1986 and 1988. The value of highest percentage is +542.13% at Chandpur (1981) and the lowest value is +16.24% at Jamalpur (1964). The meteorological factors responsible for causing excess rainfall in June months of the above mentioned years were due to early onset of monsoon, strong monsoon conditions prevailing over the country, pre-monsoon thunderstorm activities over the northern and central parts of the country and the passage of lows or well marked low pressure areas or land depressions with upper air cyclonic circulations over the country.

3.2. *July*

From the 44-year normal rainfall distribution map [Fig. 1 (b)], it has been observed that in this month highest rainfall is 901 mm at Cox's Bazar and the second highest rainfall is 780 mm at Sylhet. There are two high rainfall areas, one is in the northeastern side and another is in the southeastern and southern parts of the country. Lowest rainfall is 250 mm at Jessore and low rainfall area lies over the western, northwestern and eastern side of the country.

During the 44-year period there were in all 40 disturbances originating in the Bay of Bengal, out of which only 2 disturbances moved across the Bangladesh land area in this month.

Percentage departures of rainfall from the normals for 32 stations were calculated for each of the July months which are free from depressions and cyclonic storms. From Table 2, it has been observed that in July all the stations in the country experienced normal rainfall (+3.70% to −7.68%). Normal rainfall in July depends on the position and strength of monsoon trough of low and monsoon activities over the country.

From the lowest percentage departures of rainfall from the normals as shown in Table 3, it has been observed that different stations of the country

TABLE 3

Highest and lowest percentage departures of rainfall for different stations for individual monsoon months which did not experience depressions and cyclonic storms during 1948 to 1991

Stations	June				July				August				September			
	Highest (%)	Year	Lowest (%)	Year	Highest (%)	Year	Lowest (%)	Year	Highest (%)	Year	Lowest (%)	Year	Highest (%)	Year	Lowest (%)	Year
Barisal	136.19	1984	−63.11	1967	81.84	1959	−62.95	1986	109.68	1987	−85.48	1986	115.95	1960	−70.10	1972
Bhola	401.95	1983	−66.45	1967	—	—	—	—	536.48	1983	−70.40	1989	459.91	1982	−90.32	1972
Bogra	176.49	1973	−68.21	1983	93.85	1979	−84.76	1953	139.87	1959	−66.11	1989	173.14	1991	−67.91	1951
Chandpur	542.13	1981	−98.51	1985	781.07	1981	−86.61	1975	470.30	1981	−87.13	1973	382.18	1981	−98.02	1987
Chittagong	91.55	1954	−66.52	1967	69.64	1955	−64.71	1958	178.34	1983	−87.23	1989	130.37	1953	−65.93	1977
Comilla	103.96	1954	−73.13	1970	132.22	1948	−66.89	1987	140.74	1983	−89.38	1987	102.85	1952	−86.83	1970
Cox's Bazar	87.30	1954	−85.06	1983	68.48	1971	−96.89	1983	70.35	1965	−82.03	1986	178.39	1967	−83.86	1972
Dhaka	109.84	1984	−58.29	1958	79.79	1984	−64.70	1982	71.43	1971	−81.27	1989	136.08	1986	−68.73	1958
Dinajpur	95.47	1954	−67.67	1981	160.57	1987	−67.54	1961	145.80	1988	−63.48	1970	118.35	1991	−61.15	1968
Faridpur	124.51	1984	−66.85	1958	104.58	1974	−73.85	1983	143.56	1981	−68.65	1989	83.54	1986	−62.14	1958
Feni	93.02	1976	−60.27	1985	—	—	—	—	350.39	1982	−93.56	1985	417.96	1982	−91.33	1985
Hatiya	99.05	1978	−89.56	1983	—	—	—	—	76.29	1971	−67.20	1984	389.85	1986	−82.72	1984
Ishurdi	294.26	1977	−53.38	1986	487.35	1984	−66.11	1969	147.31	1987	−78.85	1975	120.78	1973	−70.59	1977
Jamalpur	16.24	1964	−72.31	1958	94.39	1964	−77.98	1963	55.82	1966	−68.94	1963	71.25	1964	−53.64	1967
Jessore	236.65	1986	−82.30	1958	84.85	1964	−83.16	1987	262.63	1986	−88.22	1987	150.00	1970	−79.08	1987
Kaptai	72.60	1976	−66.03	1967	130.61	1970	−60.68	1980	34.59	1971	−51.44	1975	83.38	1965	−46.13	1967
Khepupara	352.60	1983	−94.80	1984	—	—	—	—	356.23	1982	−80.76	1985	231.86	1983	−81.16	1984
Khulna	77.74	1988	−74.78	1986	126.93	1974	−91.70	1984	80.21	1987	−71.38	1989	105.45	1974	−87.73	1984
Madaripur	106.99	1985	−48.45	1986	—	—	—	—	—	—	—	—	—	—	—	—
Maijdi court	95.06	1968	−54.51	1980	105.40	1981	−97.07	1983	82.72	1982	−96.64	1983	81.30	1967	−99.10	1983
Mymensingh	46.59	1985	−73.65	1983	101.28	1989	−79.85	1950	163.00	1959	−73.73	1954	159.42	1991	−76.30	1950
Patuakhali	121.14	1977	−71.46	1986	—	—	—	—	358.79	1984	−89.93	1986	290.76	1983	−79.62	1987
Rajshahi	124.33	1973	−63.50	1967	72.37	1981	−67.27	1972	98.02	1983	−62.84	1991	100.41	1991	−71.19	1982
Rangpur	117.84	1984	−73.35	1971	171.52	1987	−66.26	1991	78.31	1988	−73.52	1973	136.27	1991	−70.59	1959
Rangamati	76.57	1976	−69.90	1985	117.38	1970	−83.30	1987	82.32	1961	−94.48	1984	318.00	1983	−96.67	1984
Sandwip	88.16	1977	−80.74	1985	—	—	—	—	91.30	1982	−79.15	1985	130.08	1967	−88.65	1984
Satkhira	109.90	1984	−80.19	1958	878.28	1981	−89.66	1966	728.57	1982	−81.23	1966	632.80	1982	−71.06	1979
Serajganj	62.73	1951	−81.67	1980	63.77	1974	−64.62	1961	112.52	1959	−61.47	1963	102.38	1973	−64.85	1966
Sitakunda	132.09	1984	−54.03	1989	—	—	—	—	—	—	—	—	—	—	—	—
Srimangal	90.94	1976	−57.95	1967	66.86	1982	−66.29	1953	70.53	1968	−43.26	1973	122.30	1982	−55.02	1977
Sylhet	57.80	1964	−57.44	1981	72.05	1989	−64.49	1958	89.14	1988	−59.11	1978	105.90	1989	−80.19	1977
Teknaf	37.51	1988	−63.44	1984	—	—	—	—	—	—	—	—	—	—	—	—

experienced severe drought conditions (−60.68% to −97.07%) in the July months of the years 1950, 1953, 1958, 1961, 1963, 1966, 1969, 1972, 1975, 1980, 1982, 1983, 1984, 1986, 1987 and 1991. The value of the highest percentage departure is −60.68% at Kaptai (1980) and the lowest value is −97.07% at Maijdicourt (1983). Drought conditions which prevailed over different stations of the country in July months of the years mentioned above are due to the prolonged 'break' monsoon or weak monsoon conditions prevailing over the country.

Also, from the highest percentage departures of rainfall from the normals as shown in Table 3, it has been observed that the different stations of the country experienced excess rainfall (+63.77% to +878.28%) in the July months of the years 1948, 1955, 1959, 1964, 1970, 1971, 1974, 1979, 1981, 1982, 1984, 1987 and 1989. The value of the highest percentage departure is +878.28% at Satkhira (1981) and the lowest value is +63.77% at Serajganj (1974). Excess rainfall over different stations of the country in July months of the years mentioned above was due to strong monsoon and passage of lows or well marked low pressure areas over the country.

3.3. *August*

Fig. 1 (c) shows that in the month of August, highest rainfall is 814 mm and 702 mm at Khepupara and Sitakunda respectively in the southeastern side and 3rd & 4th highest rainfall is 651 mm and 625 mm at Cox's Bazar and Sylhet in the southeastern and northeastern side of the country respectively. There are two regions of high rainfall, one is in the northeastern parts and another is in the southern and southeastern parts of the country. The lowest rainfall is 253 mm at Rajshahi and the low rainfall area is identified in the western and northwestern parts of the country.

During the 44-year period (1948-91) there were in all 55 disturbances originating in the Bay of Bengal out of which only 8 disturbances traversed the Bangladesh land area in the months of August.

Percentage departures of rainfall from the normals for 32 stations were calculated for each of the August months which were free from depressions and cyclonic storms and presented in Table 2. From Table 2, it has been observed that in August, the whole country experienced normal rainfall (+9.39% to −8.85%) except for Maijdicourt and Jamalpur where they experienced excess fainfall (+18.12% and +11.18%). Like July, rainfall of August month also depends upon the position and strength of monsoon trough, lows, well marked low pressure areas over Bangladesh and head Bay of Bengal. Movement of lows or well marked low pressure areas with upper air cyclonic circulations across the country also strengthens the monsoon currents and results in excess rainfall condition.

The lowest percentage departures of rainfall from the normals as shown in Table 3, indicate that different stations of the country experienced severe drought conditions (−43.26% to −96.64%) in the August months of the years 1954, 1963, 1966, 1970, 1973, 1975, 1978, 1983, 1984, 1985, 1986, 1987, 1989 and 1991. The value of the highest departure is −43.26% at Srimangal (1973) and the lowest value is −96.64% at Maijdicourt (1983). Drought conditions in August months of the years mentioned above are due to the setting in of the 'break' monsoon conditions or weak monsoon conditions prevailing over the country for long intervals of time.

The highest percentage departures of rainfall from the normals as shown in Table 3, indicate that different stations of the country experienced excess rainfall (+34.59% to +728.57%) in August months of the years 1959, 1961, 1965, 1966, 1968, 1971, 1981, 1982, 1983, 1984, 1986, 1987 and 1988. The value of the highest percentage departure is +728.57% at Satkhira (1982) and the lowest value is +34.59% at Kaptai (1971). Excess rainfall over the different stations of the country in August months of the above mentioned years was due to the movement of trough of lows or lows and well marked low pressures areas with upper air cyclonic circulations and strong monsoon activities over the country.

3.4. *September*

Fig. 1 (d) indicates that in the month of September the highest rainfall is 525 mm at Sylhet in the northeastern side and the second highest rainfall is 498 mm at Khepupara and 391 mm at Sitakunda in the southeastern parts of the country. The lowest rainfall is 196 mm at Jessore in the western side of the country and it extends upto Dinajpur; *i.e.*, northwestern side of the country.

During the 44-year period (1948-91), there were in all 68 disturbances originating in the Bay of Bengal out of which only 7 disturbances traversed the Bangladesh land area in this month.

Percentage departures of rainfall from the normals for 32 stations were calculated for each of the

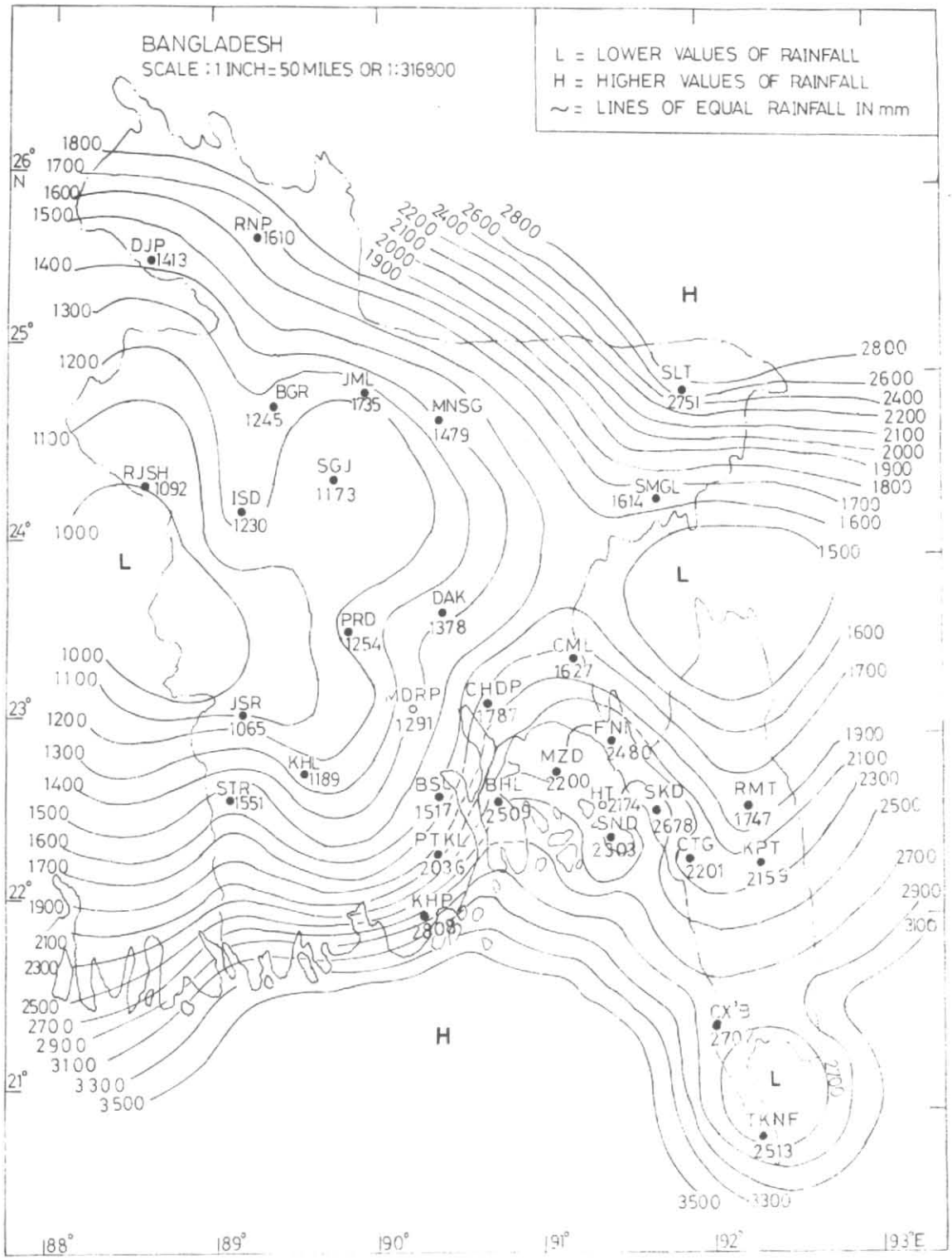


Fig. 2. Monsoon (June-September) rainfall (mm) distribution (1948-91)

September months which were free from depressions and cyclonic storms and presented in Table 2. From Table 2, it has been observed that in September, the whole country experienced normal rainfall (+9.74% to −5.28%) except Sylhet which experienced excess rainfall (+11.43%). Rainfall of September depends upon the monsoon intensity, monsoon trough, lows and well marked low pressure areas over Bangladesh and head Bay of Bengal. Movement of lows or well marked low pressure areas with upper air cyclonic circulations across the country strengthens the monsoon currents and results in excess rainfall over the country. Also, moving land depressions over the country result in excess rainfall.

The lowest percentage departures of rainfall from the normals as shown in Table 3 indicate that the different stations of the country experienced severe drought conditions (−46.13% to −99.10%) in the September months of the years 1950, 1951, 1958, 1959, 1966, 1967, 1968, 1972, 1977, 1979, 1982, 1983, 1984, 1985 and 1987. The value of the highest departure is −46.13% at Kaptai (1967) and the lowest value is −99.10% at Madaripur (1983). Drought conditions in the September months of the years mentioned above are due to setting in of the 'break' monsoon conditions or weak monsoon conditions prevailing over the country for long intervals of time and the absence of lows or well marked low pressure areas over the country. Also early withdrawal of monsoon in this months is another cause of drought conditions over different stations of the country.

The highest percentage departures of rainfall from the normals as shown in Table 3 also indicate that the different stations of the country experienced excess rainfall (+71.25% to +632.80%) in the September months of the years 1952, 1953, 1960, 1964, 1965, 1967, 1970, 1973, 1974, 1981, 1982, 1983, 1986, 1989 and 1991. The value of the highest percentage departure is +632.80% at Satkhira (1982) and the lowest value is +71.25% at Jamalpur (1964). Excess rainfall over the different stations of the country in September months of the years mentioned above was due to the strong monsoon activity, passage of lows, well marked low pressure areas and land depressions with upper air cyclonic circulations over the country.

3.5. *Monsoon season (June-September)*

Monsoon rainfall distribution map is presented in Fig. 2. It shows that highest rainfall is 2808 mm at Khepupara and 2702 mm at Cox's Bazar in the southeastern side and 2751 mm at Sylhet in the northeastern side of the country. The lowest rainfall is 1065 mm at Jessore and the second lowest value is 1092 mm at Rajshahi in the western and northwestern sides of the country.

Southern and southeastern parts of Bangladesh experience highest amount of rainfall due to the presence of orography along the east coast and the funnel shaped sea-coast of Bangladesh. Again, monsoon starts its first impact on Teknaf, Cox's Bazar, Chittagong and southeastern coastal area of Bangladesh and monsoon continues to stay there even if it withdraws from northwestern parts of the country. Also, northeastern parts of the country experience highest amount of rainfall due to orography and convergence of disturbances there. Western and northwestern parts of the country experience less rainfall due to late onset and early withdrawal of monsoon over there and absence of orographical features.

During the 44-year period (1948-91), there were in all 212 disturbances originating in the Bay of Bengal out of which 30 disturbances moved across the Bangladesh land area in the monsoon season (June-September).

Percentage departures of rainfall from the normals for 32 stations were calculated for monsoon seasons (June-September) which were free from depressions and cyclonic storms and are presented in Table 2. This table, indicates that, in the monsoon season (June-September) all the stations in Bangladesh experienced normal rainfall (+6.81% to −8.67%), and the country did not experience any drought or excess rainfall conditions during the period 1948-91.

4. Conclusions

(*i*) From the rainfall distribution pattern during the period 1948-91 for the months of June-September and monsoon season as shown in Figs. 1 (a-d) & Fig. 2, it can be concluded that they are more or less similar. But the amounts of rainfall for the individual monsoon months are different. It is observed that northeastern, southern and southeastern parts of Bangladesh experience highest amount of rainfall and western and northwestern parts experience lowest amount of rainfall. This happens mainly due to geographical position, orographical features and coastal configuration of Bangladesh and the chronological movement of onset and withdrawal process of monsoon over the country.

(*ii*) With the analysis of rainfall amount of individual observatory stations and their departures from the normals, it can be concluded that :

(a) in June — Dhaka, Khepupara, Satkhira, Serajganj, Jamalpur and Srimangal experience slight drought conditions. Dinajpur, Bogra, Rajshahi, Ishurdi, Mymensingh, Sitakunda experience excess rainfall and rest of the country experiences normal rainfall.

(b) in July to September and the monsoon season as a whole, all the observatory stations in the country experience normal to excess rainfall.

(*iii*) With the analysis of lowest departures of rainfall from the normals, it can be concluded that deficient rainfall occurs due to delayed onset of monsoon and weak monsoon conditions in June; setting in of "break monsoon" or weak monsoon conditions and absence of lows and land depressions in July and August and early withdrawal of monsoon from the country in September.

(*iv*) With the analysis of highest departures of rainfall from the normals, it can be concluded that excess rainfall occurs due to early onset of monsoon, strong monsoon conditions and pre-monsoon thunderstorm activities in June and strong monsoon conditions and passage of lows and land depressions in July to September.

(*v*) This study has thus shown that the absence of depressions and cyclonic storms from the Bangladesh land area is not the main cause of deficient rainfall or drought conditions in the individual monsoon months over different stations of the country. The country experienced normal rainfall inspite of the absence of depressions and cyclonic storms due to the occurence of other favourable meteorological situations in the monsoon season (June-September).

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