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On the aridity and drought conditions of Bangladesh

M. H. K. CHOWDHURY and M. AMIRUL HUSSAIN

Bangladesh Meteorological Department, Dacca

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सार – बंगलादेश में वर्षा की दशा सत्रीय प्रकार की होती है जिसमें जून से सितम्बर तक की अवधि में सबसे ज्यादा वर्षा होती है। वर्ष के अन्य महीनों में वर्षा कम होती जाती है। इस शोध पत्र में बंगलादेश में शुष्कता और अनावृष्टि के मासिक एवं वार्षिक अवसरों को अन्वेषित करने का प्रयास किया गया है। इसके अन्त में, 31 वर्षों (1949-1979) के वर्षा और तापमान के आंकड़ों को एकत्रित करके संशोधित किया गया है। 'शुष्कतांक' एवं अनावृष्टि अंक का इस अध्ययन में उपयोग किया गया है। यह देखा गया है कि नवम्बर से मार्च तक की अवधि में बंगलादेश के अधिकांश सभी भागों में सामान्यतया शुष्कता की स्थिति बनी रहती है जब कि बंगलादेश के उत्तरपश्चिम और पश्चिमी भागों में वैसी ही स्थिति लम्बी अवधि तक यानी अप्रैल तक बनी रहती है। बंगलादेश में अनावृष्टि की स्थिति मौसम सम्बन्धी अनियमितता एवं स्थानगत सीमा की एक परिघटना है।

ABSTRACT. Rainfall condition in Bangladesh is of seasonal type having maximum monsoonal rain during June-September. During other months of the year the rainfall intensity decreases substantially. In this paper efforts have been made to investigate into the occurrence of monthly and annual aridity and drought conditions of Bangladesh. Towards this end, rainfall and temperature data for 31 years (1949-1979) have been collected and processed. 'Aridity Index" and "Drought Index" have been used in this study. It is found that aridity condition generally exists over almost all parts of Bangladesh during November-March while the same prevails a bit longer period, *i.e*, upto April for the northwestern and western parts of Bangladesh. Drought condition is just irregular and spatially limited meteorological phenomenon in Bangladesh.

1. Introduction

Bangladesh is a country which is situated at the northern fringe of tropics. It is dominated by annual alternating winds from south-west during summer and northeast during winter resulting wet southwest monsoon and dry northeast monsoon respectively. Bangladesh, at times, experiences drought conditions having disastrous crop failure. In 1979 Bangladesh had just passed through a major drought year which was termed by many as the worst in the recent past. As the economy of Bangladesh is mainly agriculture oriented, crop failure either by the drought or flood comes as a significant strain to its socio-economic structure. In view of the national interest, a study of 31 years (1949-1979) rainfall and temperature data for 24 stations of Bangladesh was undertaken to gain insight into the details of drought and aridity conditions on the lines as was done for Sri-Lanka by Manfred Domros (1978). The aim of the present paper is to submit a report of the results obtained in the study.

2. Data source

Data used in this study have been collected from Bangladesh Meteorological Department. Efforts have been made to acquire 31 years of data (rainfall and temperature) from 1949-1979 for all the 24 meteorological stations in Bangladesh under consideration in this study. During compilation of data, some difficulties have been faced due to non-continuous nature of data both in months and years. In this context, it can be noted that the stations, *namely*, Pabna is with 19 years of data, Jamalpur and Chandpur each with 12 years of data and Rangamati and Sylhet each with 23 years of data. Efforts for finding out the estimated rainfall for the missing records of the stations as the weighted average have not been of much success. This could be due to the irregular spatial distribution of the stations. However, difficulties in filling up the missing data for some months of a few stations have been overcome by considering monthly normals of the stations. These discrepancies impose some limitations to this study. It has not been possible to study the drought and aridity conditions in the region of Tangail, Kushtia and Patuakhali due to complete lack of observational data.

3. Rainfall pattern in Bangladesh

Two monsoons are, of course, separated by two transitional seasons namely pre-monsoon and post-monsoon. Out of all these four seasons, except winter the other three contribute

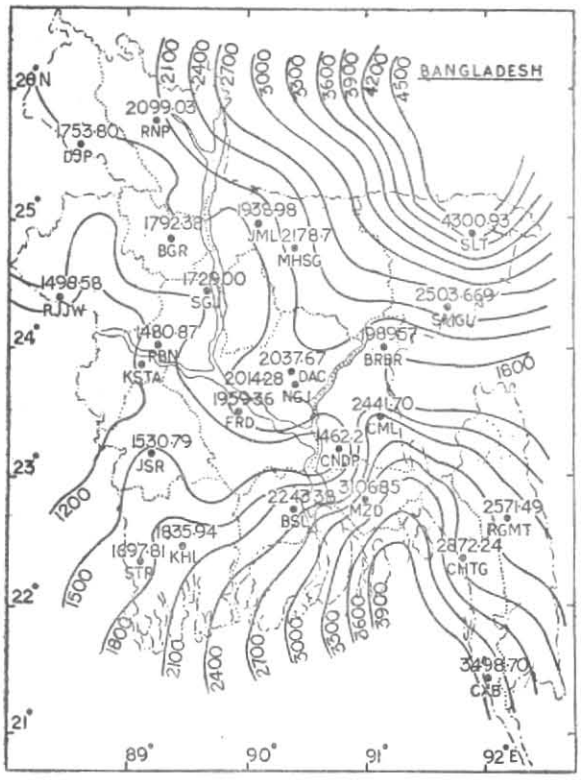

Fig.1. 31 years (1949-79) average annual rainfall (mm) distribution of Bangladesh

major share to the total rainfall of Bangladesh. However, life giving rain comes during southwest monsoon accounting for over 70 % of the total annual rainfall. It is of interest to note that the highlands situated to the east and north of Bangladesh play their due role to this monsoonal rain. Leaving aside the transition seasons, the two monsoons are quite apart in their fundamental structure, origion and airmass. In fact, the southwest monsoon is of maritime, moist and unstable air whereas the northeast monsoon is generally of continental, dry and stable air over Bangladesh. As a result, rainfall distributions in Bangladesh are basically governed by seasonally varying meteorological system of southwest monsoon as against drier northeast monsoon. This average annual rainfall distribution is shown in the rainfall distribution map (Fig. 1). Fig. 1 shows 31 years mean annual rainfall for each of the recording stations as well as the isopleths drawn representing the distribution pattern of rainfall. It can be seen that the mean annual rainfall totals range from over 4500 mm in Sylhet region to little over 1480 mm in Pabna and Rajshahi regions. This implies that the wettest region of Bangladesh is Sylhet and the driest is Rajshahi-Pabna region. It is, however, important to note that annual mean rainfall over Rajshahi is little over that in Pabna. In reality the case might be reverse if full-length of 31 years rainfall data for Pabna could have been considered. Chittagong-Noakhali region has the second highest rainfall having over 3000 mm at Cox's Bazar and Maizdeecourt. Taking account of the rainfall pattern over Bangladesh from east to west and north to south, it can be implied that the distribution in Bangladesh stretches in two directions, *namely* the spatial distribution and temporal distribution.

4. Basic consideration

Climatological water or moisture is the most important single factor which influences the drought and aridity condition. Obviously, the demand of water depends on many factors like plantation, population, crops cultivation, land-use, life style and rainfall amounts. So either unusually large demand of water or unusually small amount of rainfall and water supply from other sources can be sufficient to define the terms drought and aridity adequately. There is no single definition of drought but the concept of its definitions is mainly based on meteorological, soil-water and crop parameters. Drought is generally a temporary, recurrent and large-scale phenomenon which can occur in any temperature and rainfall condition. On the other hand, aridity bears a distinction from drought in the sense that it is a pseudo-permanent feature of low average rainfall generally dominant in the areas of high temperature.

There happens to be large variety of indices for aridity and drought condition in use. Full accounts of important drought and aridity indices are available in Technical Note No. 138 and Special Environmental Report No. 5 by WMO. Study on aridity and drought can be based either on climatological elements or hydrological factors. In the present study aridity index of de Martonne (1926) has been used to find out aridity condition of Bangladesh.

Aridity index is :

$$\text{Annual aridity} : I = \frac{P}{T+12}$$

$$\text{Monthly aridity} : i = \frac{12\,p}{t+10}$$

where $P(p)$ is the average annual (monthly) rainfall in mm and $T(t)$ is the mean annual (monthly) temperature in °C. If the index is less annual than 20, (monthly) aridity condition exists.

According to Gibbs and Maher (1967), the concepts of the limits of each decile of the rainfall distribution from a cumulative frequency curve have been used to investigate into drought

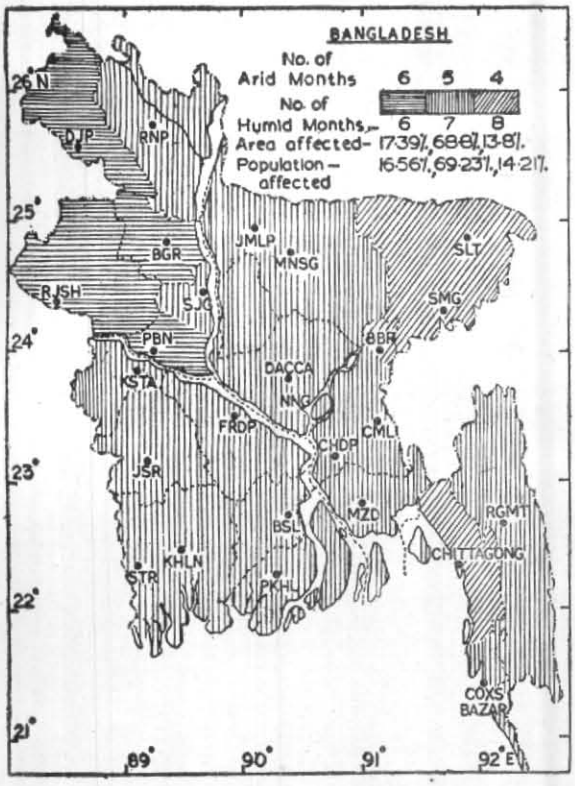

Fig. 2

conditions of Bangladesh. In this concept, the first decile gives rainfall amount, not exceeded the lowest ten per cent of totals. Thus the first decile range is that below the first decile indicating very much below normal rainfall. Similarly, the tenth decile range is above decile nine meaning very much above normal rainfall.

5. Results and discussions

5.1. *Aridity*

The use of annual aridity index of de Martonne (1926) to the rainfall and temperature observations of meteorological observatories under consideration in Bangladesh shows that no part of Bangladesh falls within the annual aridity limit of 20. Taking the driest station like Rajshahi and Pabna in the northwest, can be seen :

Rajshahi (p=1498.58 mm, T=25.60 °C, i=39.86) and

Pabna (p=1480.87 mm, T=26.06 °C, i=38.91)

The value of i in both the cases clearly exceeds the aridity limit of 20. It is, therefore, implied that Bangladesh falls outside arid-zone. Efforts have been made to deal with the detailed analysis of temporal as well as spatial occurrence of aridity in Bangladesh by the use of monthly aridity index of de-Martonne. With the use of de Martonne method, the number of arid or humid months is calculated to find out its spatial variation in Bangladesh showing area and population percentages affected due to aridity condition seasonally every year. The result is shown in the map as in Fig. 2. The map clearly shows the existence of seasonally arid conditions in Bangladesh having moderate spatial variation. Variation of the number of arid/humid months reaching a maximum of 6/6 months to a minimum of 4/8 months. This means seasonal aridity increases from 4 months (November-February) in the northeast and southeastern parts (Sylhet and Chittagong region) to 6 months (November-April) in the northwestern parts (Rajshahi, Pabna, Bogra and Dinajpur region). With this, percent of area and population affected by seasonal arid conditions increases from 13.8% and 14.21% in the northeastern and southeastern parts to 17.39% and 16.56% respectively in the northwestern parts of Bangladesh, whereas the maximum area and population percentage, *i.e.*, 68.81% and 69.32% respectively are found to be affected by five arid months every year, and this maximum is obviously in between these two extremes. It can, therefore, be inferred that Bangladesh with its regions having seasonal period between 4 and 6 arid months with respect to period between 8 and 6 humid months can hardly be termed as arid or semi-arid country.

5.2. *Drought*

In order to apply drought index, an initial methodological procedure has been followed. At the beginning, square roots of rainfall data (in mm) of the study period for each station have been grouped in the range of 5 mm and as such there is a variation of group numbers from station to station depending on the variation of the total annual rainfall. Then frequency density and cumulative frequency have been calculated. By taking square roots of the rainfall (in mm) as abscissa and frequency density as the ordinate, the decile curve is constructed for each station. As already mentioned, the first decile range and the tenth decile range in respect of Gibbs and Maher (1967) have been considered as abnormally dry or drought and abnormally wet conditions respectively for each station. The drought years with corresponding annual rainfall and drought index for each meteorological stations of Bangladesh are shown as bar-diagrams in Fig. 3. From Fig. 3, evidence of the occurrence and frequency of drought in different regions of Bangladesh during the years under study can be clearly seen. It can be observed that Chittagong region is completely drought-free but its southern most part around Cox's Bazar has an incidence of two drought years in 1951 and 1972. It is of interest to note that Bogra and Noakhali

TABLE 1

Area and population percentage of Bangladesh under drought conditions based on period 1949-1979

Year	Percentage of area	Percentage of population
1950	13.79	14.13
1951	31.63	31.51
1952	6.57	5.95
1954	3.43	3.92
1955	9.83	15.49
1956	11.25	9.53
1957	46.54	53.03
1958	37.47	36.24
1960	2.70	3.11
1961	22.39	20.76
1962	11.30	9.74
1963	8.60	6.63
1966	18.42	16.54
1970	9.10	10.55
1971	4.80	5.66
1972	42.48	43.05
1976	5.02	5.48
1978	3.66	4.51
1979	42.04	43.90

Note : 1. Completely drought-free years : 1949, 53, 59, 64, 65, 67, 68, 69, 73, 74, 75, 77.

2. Completely drought and semi-drought-free years : 1949 53, 59, 73, 77.

regions have the maximum number of drought years. It can be further seen, in the year 1979 known as drought year for Bangladesh areas like northern parts of Sylhet, Jessore, Rajshahi, Dacca, Faridpur and Barisal are found to be free from the incidence of heavy drought. In some district regions having more than one observational stations it can be seen that the drought year numbers are not the same. This can be the fact, but the other reason for such anomaly can be attributed to the lack of full-length data period under study. From the drought years ob-

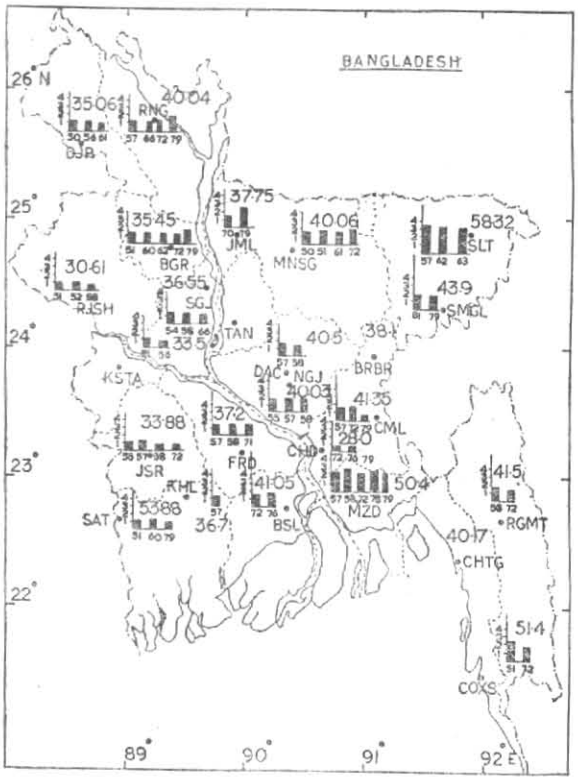

Fig. 3. Drought years showing corresponding annual rainfall (mm $\times 10^3$) with drought index for each station. Number in bold at the top of each histogram indicates drought index for respective station

tained, it is quite difficult to identify a clear periodicity from the incidence of drought in Bangladesh. Fig. 3 also demostrates the characteristic irregularity in the spatial distribution of drought condition in Bangladesh. It can be further seen from Fig. 3 that the value of the first decile range indicating drought condition varies from region to region in Bangladesh. It is thus highest (*i.e.*, 58.32) in Sylhet region situation in the north-eastern part and lowest (*i.e.*, 30.61) in Rajshahi region in the north-western parts of Bangladesh.

The area and population percentages of Bangladesh subjected to annual drought condition during the study period (1949-1979) have been investigated and shown in Table 1. It can be seen from the table that the drought conditions never affect the whole country with its total population in any drought year. In fact, drought is a spatially limited phenomenon, affecting only small parts of Bangladesh. From the table, it is interesting to note that Bangladesh experienced severe drought condition in 1957 having 46.54 and 53.03 as percentage of area and population affected respectively. The area and population percentages affected during drought condition in 1979 are 42.09 and 43.9 respectively. The table

TABLE 2

Percentage probability of drought

	Percentage area										
	100	90	80	70	60	50	40	30	20	10	
	91	81	71	61	51	41	31	21	11	5	5 Nil
Frequency	0	0	0	0	0	3	2	1	4	5	4 12
%Probability of drought	0	0	0	0	0	9.68	6.45	3.23	12.9	16.13	12.9 38.71

also shows that the incidence of drought conditions irrespective of population and area percentages in more than one or two consecutive year, is not uncommon. Out of 31 years under study, Bangladesh experienced 12 completely drought free years and 5 completely drought as well as semi-drought free years.

From the frequency of drought incidence in Bangladesh for years from 1949-1979, the probability percent of annual drought conditions for a given percentages of the total area of Bangladesh has been calculated and shown in Table 2. This table shows that drought can affect Bangladesh in about 7 to 8 years less than 5 per cent and 11 to 20 per cent, 6 to 7 years only 5 to 10 per cent, 30 to 31 years 21 to 30 per cent, 15 to 16 years 31 to 40 per cent and 10 to 11 years 41 to 50 per cent of total area of Bangladesh. It is almost impossible that more than 50 per cent area of Bangladesh could be affected by drought condition in any single year. It can also be seen that the drought free condition in Bangladesh can occur once in every 2 to 3 years.

6. Conclusion

The discussions presented in this study based on 31 years rainfall and temperature data lead to the following conclusions :

(*a*) Though Bangladesh is free from annual aridity condition, there is existence of seasonal aridity in Bangladesh having maximum number of arid months (upto 6 months) in the northwestern parts to a minimum of 4 months in the northeastern and southeastern parts of Bangladesh. The per cent of area and population affected by maximum arid months in the northwestern parts do not exceed 17.39% and 16.56% respectively.

(*b*) Drought is a temporary, spatially irregular and non-periodic phenomenon affecting small parts of Bangladesh. While only Chittagong region is completely drought-free except its southern tip, Bogra and Noakhali have the maximum number of drought years.

(*c*) The value of first decile range, as per Gibbs and Maher (1967), indicating drought conditions in Bangladesh varies from region to region reaching from the lowest value (30.61) in Rajshahi region to the highest (58.32) in Sylhet region.

(*d*) Bangladesh has never been wholly affected by drought conditions in any drought year during the study period. The highest percentages of area and population subjected to the incidence of drought in 1957 are 46.54% and 53.03% respectively.

(*e*) Only less than 5 per cent and 41 to 50 per cent of the total area of Bangladesh can be affected by drought in about 7 to 8 years and 10 to 11 years respectively. It is almost impossible for Bangladesh to be affected with its area more than 50 per cent by drought condition in any single year.

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