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# Diagnosis of Drought in Bangladesh using Standardized Precipitation Index

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***Abstract*—The drought events are diagnosed from the monthly rainfall data of Bangladesh Meteorological Department over Bangladesh using Standardized Precipitation Index (SPI) during 1961-1990. The historical records of drought event obtained from Bangladesh Bureau of Statistical and International Disaster Database are used to verify the SPI results. SPI is calculated at 27 locations over Bangladesh. To see the drought phenomena in regional scale, the SPI is also calculated at 4 sub-regions over the country. It is found that regional information is better in drought diagnosis compared to point information. The regional analysis is able to detect about 87 per cent (13 out of 15) of the drought events occurred during the study period. This study disclosed that the frequency of moderate drought is higher for all over the country. The central, the northern and the southwestern regions are the most severe drought prone area over Bangladesh.**

***Keywords- drought, Bangladesh, standardized precipitation index, rainfall***

## I. INTRODUCTION

Meteorological drought is a short lived, recurring natural disaster, which originate from the lack of precipitation and can bring significant economic losses [1]. It is not possible to avoid meteorological droughts, but it can be monitored, and their adverse impacts can be alleviated [2]. The success of the drought prediction depends on how well it is defined and identified.

Bangladesh is one of the most seriously affected countries suffering from various meteorological disasters such as droughts and tropical cyclones in the pre- and post-monsoon seasons and floods in the summer monsoon season. Due to the global warming, in South Asia most of the climate models project a decrease in precipitation during the dry season and increase during the monsoon season [3]. This will cause a combination of more extreme droughts and floods in this region. According to the report of National Drought Mitigation Center of year 2006, Bangladesh has already shown an increased frequency of droughts in recent years. Additionally, agriculture, power generation and industrial production depend upon precipitation [4]. Due to the critical influence of large variability of precipitation, detection of drought becomes very important for policy making efforts too [5]. Now-a-days food security is an important issue in the World. Because drought is intimately related with food security, therefore, study on drought hazards especially drought monitoring are essential for implementing mitigation to reduce drought impact in Bangladesh. In Bangladesh, several researches have been investigated drought impact on agriculture, food production, economy, and society [6 and 7]. Up-to-date, so far there is no standard drought index method has been used for drought diagnosis in Bangladesh. The aim of the present study is to diagnose the spatial and temporal pattern of drought using a standard drought index method.

## II. DATA AND METHODS

Bangladesh Meteorological Department (BMD) rainfall data of 27 stations from 1961 to 1990 are used. Historical record of drought events of Bangladesh obtained from 'Agricultural Statistics Year Book of Bangladesh' published by Bangladesh Bureau of Statistics (BBS) and International Disaster database (EM-DAT) archive data available from 1971 to 1990 are also used for this study.

Station names over Bangladesh are shown above the station location (plus mark, Fig. 1a) and elevation (below plus mark in Fig. 1a). The circle is used with plus marks to indicate the stations which are used in detail study. These stations are namely Rangpur, Dhaka, Khulna, Cox's Bazar and Sylhet. To analyze the drought condition of entire country, 27 BMD stations are divided into four sub-regions as shown in Fig. 1b, based on the topography and rainfall anomalies, named: (i) northern, (ii) central, (iii) eastern, and (iv) southwestern.

In order to investigate the spatial and temporal extents and severity of drought that occurred in the study area, Standardized Precipitation Index (SPI) [8] is calculated. SPI is based on the precipitation on multiple time scales and widely used for drought detecting and monitoring. Several researches [8, 9 and 10] showed that the SPI is a good tool for detecting and monitoring drought. An analyst with a time series of monthly precipitation data for a location can calculate the SPI for any month in the record for the previous i months, where i=1, 2, 3, 12... 24... 48 ... depending upon the time scale of interest. Hence, the SPI can be computed from precipitation for 1 month to 48 month length. The range of SPI in different drought categories is shown in Table I.

The negative values of SPI are considered as dry and positive values for wet periods. SPI is calculated for 1, 3 and 6 month time length (hereafter M1, M3, and M6) for a short-term-length and 9, 12 and 24 month length (hereafter M9,

M12, and M24) for long-term-length drought detection. This study computes SPI at 27 stations and 4 sub-regions of Bangladesh from BMD monthly rainfall data.

## III. Results and Discussion

The SPI is calculated for 1 month (M1), 3 month (M3), 6 month (M6), from the station rainfall data at 27 stations during the study period (1961-1990). Details studied stations are Rangpur, Dhaka, Khulna, Sylhet, Cox's Bazar out of 27 stations. Rangpur experienced moderate to severe droughts for several years. The moderate drought (SPI $\leqslant$ -1) is observed in the year of 1962, 1963, 1966, 1967, 1970, 1974, 1976, 1980, 1982, 1989 and extreme drought (SPI$\leqslant$-2) is detected in the year of 1967, 1972, 1973, 1976, and 1982 (not shown). Patterns for M1, M3, and M6 are almost similar with a small shift and it is difficult to differentiate among the short-month-length. The patterns of SPI values for Dhaka, Khulna, Sylhet, and Cox's Bazar stations are quite similar to Rangpur station but the magnitudes and occurrence year of drought are different for different stations. It is difficult to differentiate among the SPI time series. Due to station point information used in calculation of SPI, the drought years are not possible to detect from the station point data. Therefore, regional average of neighbor stations may provides better performance of using the SPI for drought analysis because it is a regional phenomenon.

The historical record of drought events confirmed drought in during 1973 - 1976 and 1979 - 1989 at different regions of Bangladesh. Drought with moderate intensity occurred all over the country from 1981 to 1984. Historical records show that most of the drought events within the study area were in 3 to 6 month length period. Therefore, short-month-length SPI results have taken into consideration for analysis.

TABLE I. Drought categories defined for SPI values with Corresponding Cumulative Probability in Relation to the Base Period.

| Cumulative Probability | SPI value | Drought category |
|---|---|---|
| 0.0014 | -3.0 | Extreme drought |
| 0.0228 | -2.0 | Severe drought |
| 0.1587 | -1.0 | Moderate drought |

The SPI calculated in 1 month (M1), 3 month (M3), and 6 month (M6), lengths for the four sub-regions during the study period (1961-1990) are shown in Fig. 2. The intensity and frequency of drought are different in spatial and temporal extent. In the central sub-region moderate droughts (SPI$\leqslant$-1) are identified in the year of 1962, 1965, 1970, 1975, 1977, 1980, 1982, 1986, 1989, whereas extreme droughts (SPI$\leqslant$-2) are detected in the year of 1963, 1973 and 1979. The drought year obtained from regional analysis matches well with the historical records of actual events (Table II). Similarly, drought frequency for the northern, the southwestern and the eastern sub-regions are similar to the actual events. Table II shows that regional analysis detected 13 out of 15 drought events in SPI calculation. Thus, the results obtained from regional data are better in drought diagnosis.

The exact drought month or year in a particular region is not easy to obtain from the SPI graphical patterns. So, statistical counts of drought spell from SPI values can be used to obtain the overall drought characteristics in Bangladesh. Table III describes drought situation in terms of frequency and intensity. Frequency of moderate drought is higher than the others. Moreover, in the central and southwestern sub-regions, mostly droughts with moderate intensity are occurred.

## IV. Conclusions

Drought condition over Bangladesh is analyzed using Standardized Precipitation Index (SPI) from the rainfall data of Bangladesh Meteorological Department at 27 stations during 1961 to 1990. In this investigation it is evident that, SPI calculation over a region provides better consistency of drought situation instead of single station information.

TABLE II. Historical records of drought year (DY), drought affected region (DAR) and detection of drought from regional analysis using SPI over Bangladesh during 1973 to 1990.

| DY | DAR | SPI |
|---|---|---|
| 1973 | northern | detected |
| 1974 | northern, southwestern | detected |
| 1975 | northern, central, southwestern | detected |
| 1976 | northern, southwestern | detected |
| 1979 | northern, central | detected |
| 1980 | northern, southwestern | detected |
| 1981 | throughout country | detected |
| 1982 | throughout country | detected |
| 1983 | throughout country | detected |
| 1984 | throughout country | not detected |
| 1985 | northern, central, southwestern | not detected |
| 1986 | northern, central, southwestern | detected |
| 1987 | northern, southwestern | detected |
| 1988 | northern, southwestern | detected |
| 1989 | northern, southwestern | detected |

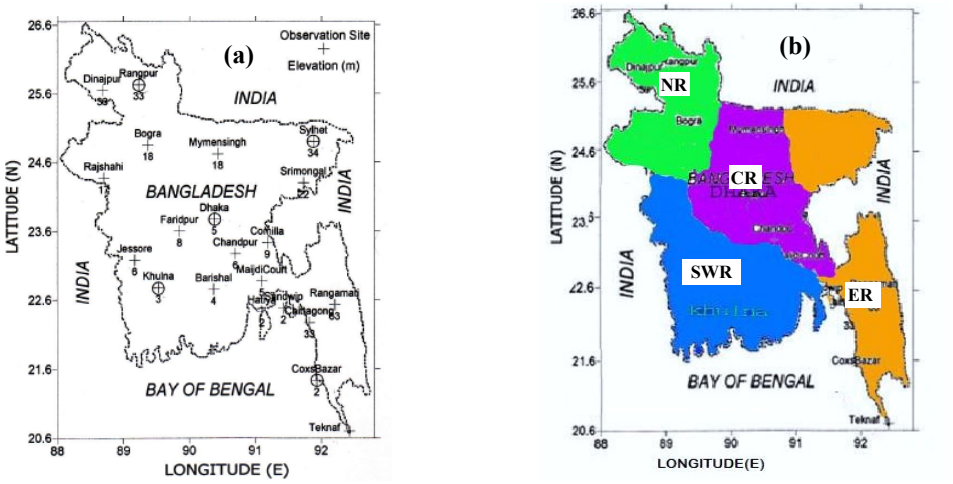


Figure 1. Map of Bangladesh with (a) the name of observation sites, location, elevation (in m), and detailed analyzed stations (circle) and (b) northern region (NR, green), central region (CR, violet), eastern region (ER, orange) and southwestern region (SWR, blue).

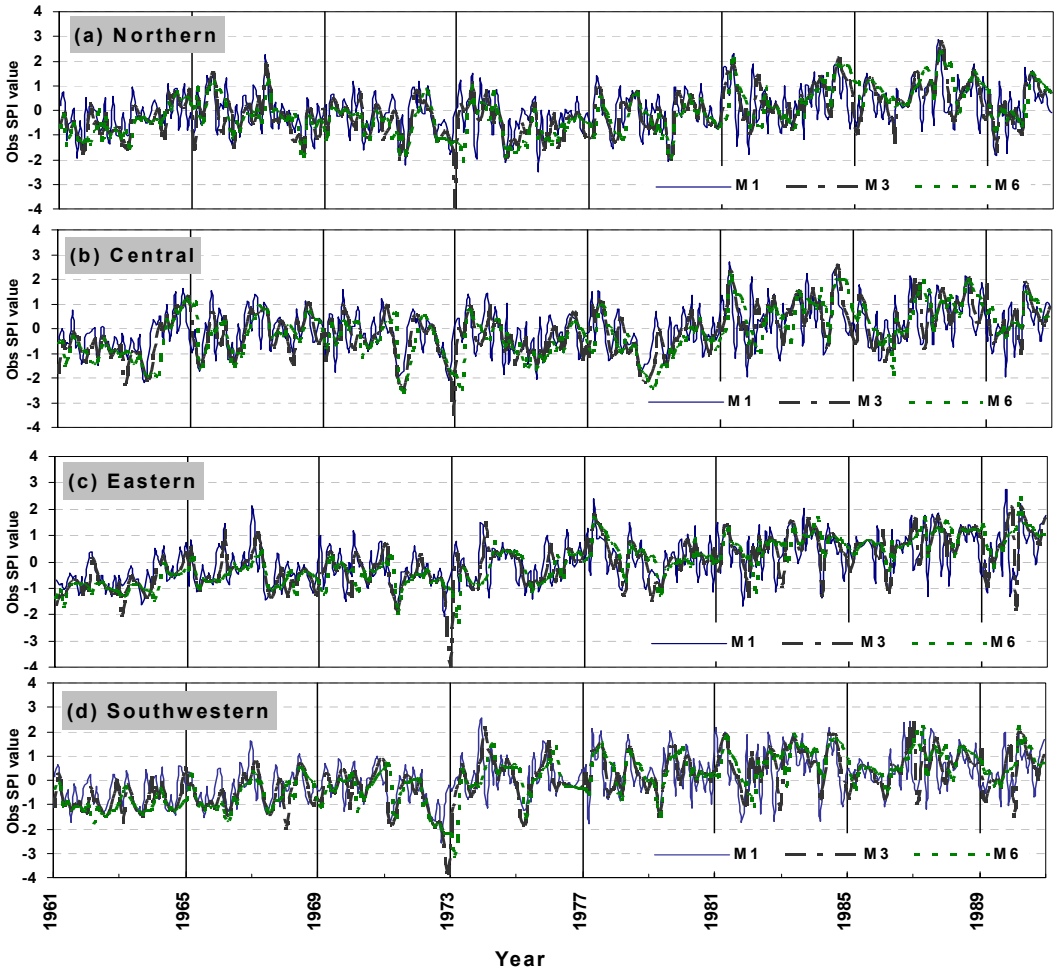


Figure 2. The SPI values calculated from regional rainfall data for 1 month (M1), 3 month (M3) and 6 month (M6) length at (a) northern (b) central (c) eastern and (d) southwestern sub-regions of Bangladesh during 1961 to 1990.

TABLE III. FREQUENCY OF DROUGHT IN BANGLADESH FOR DIFFERENT SHORT-MONTH-LENGTH USING SPI CALCULATED FROM THE REGIONAL AVERAGE OF STATION DATA.

| Sub-regions | Month 1 | | Month 3 | | Month 6 | |
|---|---|---|---|---|---|---|
| | ***Moderate Drought*** | ***Severe Drought*** | ***Moderate Drought*** | ***Severe Drought*** | ***Moderate Drought*** | ***Severe Drought*** |
| central | 52 | 3 | 49 | 10 | 58 | 8 |
| northern | 32 | 4 | 50 | 4 | 58 | 1 |
| eastern | 35 | 1 | 45 | 3 | 39 | 2 |
| southwestern | 44 | 2 | 49 | 4 | 62 | 3 |
| Bangladesh | 163 | 10 | 193 | 21 | 217 | 14 |

In addition, drought index results agree with the historical record for the duration of drought (3-6 month) with some exceptions. To count the drought spell, a statistical score is prepared. The frequency of moderate drought is higher for all over Bangladesh. The central, northern and southwestern sub-regions are the most drought prone area where severe drought has often occurred as well.

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