Assessment of Spatial and Temporal Drought Pattern in Bangladesh

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The 7th International Coordination Group (ICG) Meeting
GEOSS Asian Water Cycle Initiative (AWCI)
Tokyo, Japan, 5-6, October 2010

Introduction

- Drought assessment in Bangladesh plays an important role for a sustainable use of limited water resources as well as for rain fed agricultural production.

- Increasing dryness and drought will adversely affect the agricultural activities of the country if the phenomenon is not assessed properly as well as timely and adequate adaptation measures are not implemented.

Introduction

- Many studies are there to assess the flood scenario in Bangladesh, whereas studies on drought in Bangladesh are very few.

- This study focuses on the characterization, assessment, quantification of drought severity; drought vulnerability and damage; and prioritization of potential adaptation measures against drought in Bangladesh.

Objectives of the Study

- To define drought conditions and classify degree of drought from the context of Bangladesh.
- To assess the spatial and temporal variations of drought in Bangladesh.
- To identify the spatial expansion of increasing and persistent drought throughout the country.

Objectives of the Study

- To determine drought occurrence probability throughout the country.
- To develop a method for drought quantification and analyze areas of drought vulnerability as well as drought severity in Bangladesh.
- To develop drought index considering the geographical as well as climatic condition of Bangladesh.
- To develop drought damage curves as well as quantify drought damage.

Study Stations

- Among 34 BMD stations, 23 stations having representations from all regions of the country have been selected for this study.
- For the convenience of the study, Bangladesh has been divided into five regions, namely North-West, North-East, South-West, South-East and Central regions.
- Central Region: Dhaka, Mymensigh, Comilla, Tangail, Chandpur

Study Stations

- North-Western Region: Dinajpur, Rangpur, Rajshahi, Bogra, Chuadanga
- North-Eastern Region: Sylhet
- South-Western Region: Barisal, Bhola, Khulna, Faridpur, Madaripur, Satkhira, Patuakhali, Jessore
- South-Eastern Part: Feni, Cox's Bazar, Chittagong, Rangamati

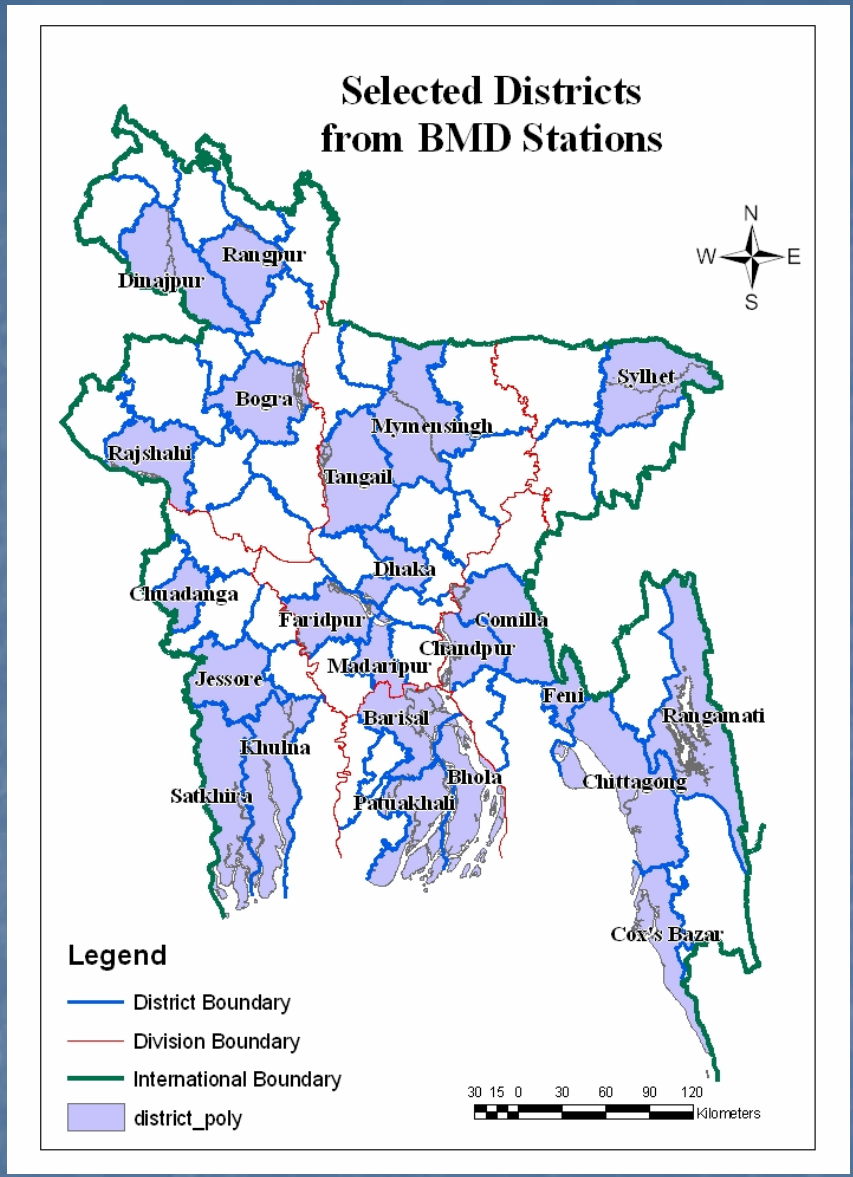

Figure 1: Study Area Profile

Analyses and Results

- ***Trend of Climatic Parameters in Bangladesh***

- Dryness and drought are the phenomena derived from the imbalance in climatic parameters.

- In this study, the trends of seasonal as well as annual rainfall and seasonal temperature have been analyzed to get the patterns of seasonal dryness and drought in Bangladesh.

Seasonal Rainfall Patterns

- Decrease in rainfall, when it is expected, can be considered as an indication of drought.

- To assess seasonal drought in Bangladesh, long term patterns of seasonal rainfall have been observed in this study.

- North-west region of the country is generally considered as the drier one. Observations on Rajshahi show that rainfalls have been increased over the considered period of time in all seasons except in monsoon.

Findings:

- Regional Patterns:
- Temporal plots of the seasonal rainfall at all stations of the north-west region have shown increasing trends except in Rajshahi during monsoon and in Chuadanga at winter.

- Pre-monsoon, monsoon and winter have become drier in Comilla due to decreasing trends of rainfall in central region.

- In the south-west region, significant decreases of rainfall have been observed in Faridpur during monsoon, in Madaripur during pre-monsoon and in Bhola during post-monsoon as well as at winter.

- In south-east part, pre-monsoon and monsoon rainfalls have been decreased during pre-monsoon and monsoon respectively.

- Seasonal Patterns:
- Madaripur has the maximum negative slope of 9.61 mm/year, which indicates the station getting the highest dryness over time during pre-monsoon. Again the rate of getting dryness is the minimum in Chandpur having the minimum negative slope of 0.38 mm/year.

- Comilla has got the driest monsoon with the rainfall trend having maximum negative slope of 12.41 mm/year during monsoon.

- The negative slope of temporal trend of post-monsoon rainfall is the maximum in Comilla (-1.48 mm/year), indicating the driest post-monsoon in Comilla.

- The rate of decrease of winter rainfall is the maximum in Tangail, which is indicated by the maximum negative slope of 2.20 mm/year.

Seasonal Temperature Patterns

- Increase in temperature instigates increase in evaporation as well as evapotranspiration and hence decrease in available water.

- Therefore, increase in seasonal temperature is a critical issue to be studied to assess seasonal drought scenario throughout the country.

Findings:

- Regional Patterns:
- In the north-west and north-east regions of the country, no occurrence of increasing temperature has been found, rather temperatures have been observed to decline over the considered period of time.

- In central region, monsoon and post-monsoon temperature have been increased in Dhaka. Monsoon temperature has also been increased in Tangail of this region.

- From the temperature patterns of south-west region, it is found that monsoon temperature has been increased in Barisal and Satkhira.

- Analysis on south-east region of the country represents that post-monsoon temperatures have shown increasing trends in Feni, Chittagong and Cox's Bazar. Again, monsoon temperature has been found to be increased in Cox's Bazar.

- Seasonal Patterns:
- The maximum positive slope of temperature trend has been found as 0.03 °C/year in Tangail, indicating maximum dryness among other drier stations during monsoon.

- Faridpur has become the driest having the maximum positive slope of post-monsoon temperature of 0.03 °C/year.

- The maximum positive slope of winter temperature trend has been found in Patuakhali as 0.13 °C/year.

- It can be noted here that monsoons in Faridpur and Cox's Bazar have become drier due to decreased rainfall (-2.21 mm/year and -0.07 mm/year respectively) as well as increased temperature (+0.02 °C/year and +0.01 °C/year respectively).

Defining Drought Criteria

- Different dryness conditions have been defined based on the threshold values of temperature and rainfall.
- Threshold value, considering rainfall or temperature may be considered as a reference value, deviation from which will indicate the extent of dryness and drought in extreme conditions.
- These values vary depending on seasons and locations.

Calculation of Threshold Values

- For calculating the threshold value for a particular season of a specific location,

- Seasonal rainfall for each year is subtracted from the seasonal average rainfall.

- The negative values indicate the shortage (deviation) in rainfalls from the seasonal average.

Calculation of Threshold Values

- Again the average of the negative values indicates that on an average (generally) rainfall shortage attains that value.

- Finally, the threshold value (in case of rainfall) is determined by the following equation:

Threshold rainfall = ∑(Seasonal average rainfall + Average of negative deviations)

Threshold temperature = ∑(Seasonal average temperature + Average of positive deviations).

Development of Dryness Maps

- In this study, semi-arid, arid and drought conditions have been defined depending on the deviation of rainfall or temperature from the threshold values.

- Here, different dryness conditions have been identified by different indices, such as index 1 indicates normal (non-dry condition), 2 for semi-arid, 3 for arid and 4 for drought condition.

Drawback:

- It is evident that a particular area may seem to be dry considering one parameter, i.e., rainfall, while it may not be dry according to other parameter, i.e., temperature.

- In 1999, winter rainfall threshold criteria indicate drought condition in Dinajpur, whereas the temperature threshold indicates semi-arid condition in the same station.

Recommendation:

- Correlation between temperature and rainfall changes can be analyzed.

Regional Patterns of Seasonal Dryness Slope

- 'Slope of Dryness' or 'Dryness Gradient' has been defined as the temporal variation in dryness pattern for a particular area, in other word, temporal change in dryness rate for a specific area.
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- In each graph, the abscissa represents year, whereas the ordinate indicates the dryness indices, i.e, 1 for normal (non-dry) condition, 2 for semi-arid, 3 for arid and 4 for drought condition.
- A positive slope indicates the increase of dryness, a negative slope indicates the decrease of dryness and a zero slope means no change in dryness condition.

- Figure 7 shows that consideration of seasonal rainfall has produced positive dryness gradients during all of the four seasons in the north-west region of the country.

- On the other hand, consideration of seasonal temperature has produced positive dryness gradient during post-monsoon, negative gradients during pre-monsoon and winter

Areas with Persistent Dryness

- Comparing the rainfall and temperature of two successive years, 1996-1997, 1997-1998, 1998-1999 and 1999-2000, the areas suffering from dryness in both of the successive years, have been identified.

- These areas have been defined as areas with persistent dryness.

Drought Patterns in Bangladesh

- ***Discrete Rainfall Anomalies***
- Rainfall anomaly is the measurement of rainfall deviation from long-term mean of rainfall records.
- The negative deviation indicates the shortage of rainfall from the long-term mean rainfall.
- The positive deviation measures the tendency of water availability compared to the long-term average.

- The time series of pre-monsoon rainfall anomalies shows that Dhaka has experienced below-normal rainfall and hence dry period for an extended period from 1953 to 1963.

- During the most severe shortage of rainfall in 1979, pre-monsoon rainfall was 29% of the long-term average.

- Again, extended drought period has been returned during 2002 to 2008, where 2005 has shown above-normal rainfall in Dhaka.

- During monsoon, rainfall shortage is not so remarkable in Dhaka.
- Rainfall shortages have been found during 1958, 1977 and 1994, when the rainfalls were 52%, 59% and 62% of the long-term average respectively.
- The years got significant shortages in post-monsoon rainfall are 1957, 1981 and 1997 in Dhaka.
- Extended dry winter periods are found from 1953 to 1956, 1959 to 1963, and 1965 to 1972 in Dhaka.

- Severe dry periods were 1969 in Rajshahi, 1973 in Sylhet, 1978 in Jessore and 1972 in Chittagong.

- The increase in rainfall anomalies indicates the more random patterns of drought occurrences.

Cumulative Rainfall Anomalies

- The monthly rainfall anomalies have been aggregated to get the cumulative rainfall anomalies for each of the considered year for each station.

- It depicts the aggregate amount as well as the duration of water surplus or deficit.

- The relative importance of the cumulative rainfall anomaly depends on the magnitude of the anomaly in relation to normal conditions.

- To account for this effect, the monthly cumulative anomalies have been expressed in thousandths of the corresponding annual rainfall.

- Depressed rainfall anomalies –
- In Dhaka from 2001 to 2004
- In Sylhet the period is from 1960 to 1964, 1965 to 1966 and 2003 to 2004
- In Jessore the period extends from 1951-1953 and from 1957 to 1959
- In Chittagong the period is from 1957 to 1959.

- These periods with depressed i.e., negative rainfall anomalies indicate drier periods in these stations.

- ***Rainfall Anomaly Index (RAI)***
- Rainfall Anomaly Index has been used to address the annual rainfall variability of the considered stations throughout the country.

- Again, the rainfall variability can be used to analyze the variable drought patterns in the country.

- Minimum Rainfall Anomaly Index-
- -8.95 in Dhaka (1974)
- -7.48 in Rajshahi (1969)
- -10.81 in Sylhet (1973)
- - 7.13 in Jessore (1978)
- -4.34 in Chittagong (1972)

- The periods showing maximum depressed rainfall anomalies also have the minimum Rainfall Anomaly Index (RAI), which again indicate drier periods.

- For example, severe dry period has been found in Rajshahi in 1969, again the minimum RAI (-7.48) in Rajshahi has also been found in 1969.

Drought Quantification in Bangladesh

- The precise quantification of drought is a difficult task.
- Again, the drought assessment methods developed yet are region specific.
- Therefore, the assessment as well as quantification methods for drought used in other regions may not give the traditional results in Bangladesh.

- Monsoon rainfall intensity has been decreased in Dhaka, Comilla, Bhola, Faridpur, Chittagong and Cox's Bazar.

- The maximum decrease in monsoon rainfall intensity has been found in Comilla where the rainfall intensity slope is -0.006 mm/hr/year.

- The maximum increase in monsoon rainfall has been found in Chuadanga, where the slope of rainfall intensity is +0.007 mm/hr/year.

- ***Spatial Variation of Seasonal Normalized Rainfall Intensity***

- Rainfall intensity maps have been developed to demonstrate the spatial patterns of rainfall intensity.

- These maps can be used to visualize drought tendencies throughout the country.

- The rainfall intensities, characterizing drought conditions, are
- 0.00-0.29 mm/hr in pre-monsoon,
- 0.00-0.45 mm/hr in monsoon,
- 0.00-0.17 mm/hr in post-monsoon and
- 0.00-0.03 mm/hr in winter.

- Winter drought is prominent in north-west, south-west, south-east and central region of the country.

- Rainfall intensity maps have been drawn considering the rainfall intensity distributed uniformly over the area.

- In actual case, the distribution is not uniform and to account for this effect, rainfall intensity contour maps have been developed.

- *Drought Area Index (DAI)*

- Drought Area Index is a method to quantify drought intensity and the calculations of the index depend on the prior month's value of drought intensity.

- The values of drought intensity have been plotted against months of a year.

- The negative ordinates of these plots represent higher drought intensity, whereas the positive ordinates indicate lower drought intensity as well as no occurrence of drought.

- Thus, DAI gives a scale to measure drought intensity.

- Using the rainfall parameters mentioned in Table 10, Drought Severity Indices have been determined.
- For example, the Drought Severity Indices based on quartile range for Dinajpur are given as follows:
- Cumulative Rainfall (CR) < 1910 mm – Driest period
- 1910 mm ≤ CR < 21552 mm – Dry period
- 21552 mm ≤ CR < 71214 mm – Near Normal period
- 71214 mm ≤ CR < 98203 mm – Wet period
- CR ≥ 98203 mm – Wettest period

- ***Rainfall Anomaly Percent from Normal***
- The ratio of seasonal rainfall to log-term seasonal average, also called normal seasonal rainfall indicates the departure or anomaly of seasonal rainfall from the normal.

- The ratio multiplied by 100 then indicates the anomaly percent from normal.

- The seasons having anomaly less than 75% have been termed as dry seasons while the seasons with anomaly more than 125% are termed as wet seasons.

- During post-monsoon and winter dry periods are more than the wet periods (Table 12).

- During post-monsoon, the percentages of dry years are 38% in Dhaka, 36% in Rajshahi, 36% in Sylhet, 42% in Jessore and 36% in Chittagong.

- Again, during winter the percentages of dry periods are 47% in Dhaka, 50% in Rajshahi, 44% in Sylhet, 53% in Jessore and 61% in Chittagong.

Assessment of Drought Potential in Bangladesh

- ***Stochastic (Random) Component Time Series (SCTS)***

- Stochastic Component Time Series value for each year is calculated by dividing the difference between total and mean annual rainfall by the standard deviation of rainfall for each year.

- Then these values of SCTS have been plotted against the considered period of time.

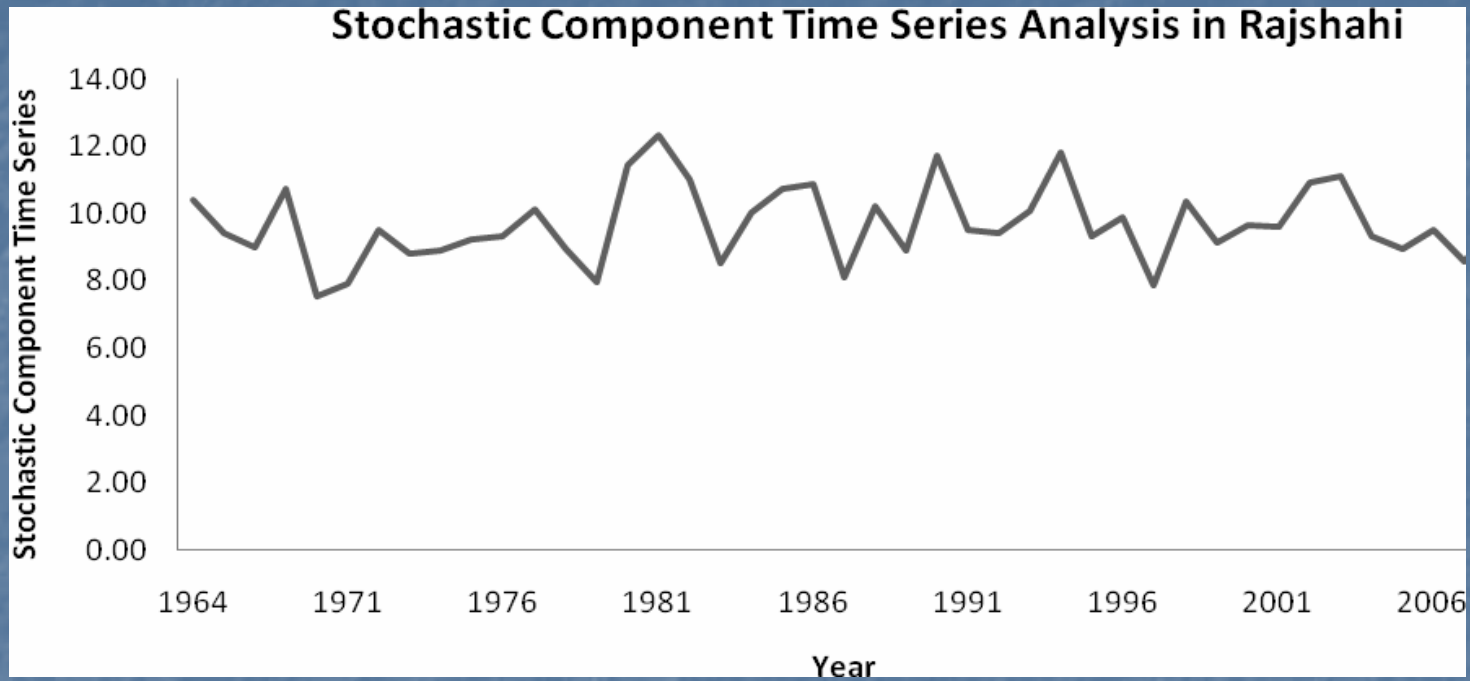

Figure 17: Temporal Trends of Stochastic Component Time Series in Rajshahi

- The probability of –

- high drought - highest in Comilla (61%) and the lowest in Dinajpur (2%).

- Moderate drought - highest in Rangamati (70%) and the lowest in Comilla (36%).

- Low drought - maximum in Dinajpur (39%) and the minimum in Comilla (3%), Satkhira (3%) and Bhola (3%).

Upper Confidence Level of Temperature and Lower Confidence Level of Rainfall

- In this study, 95% confidence level has been used to calculate the upper confidence level of temperature as well as lower confidence level of rainfall.

- The concept used here is that if the lower confidence level of rainfall decreases and at the same time the upper confidence level of temperature increases, then the phenomenon indicates the probability of drought occurrence.

- In Rajshahi the lower confidence level of monsoon rainfall has shown the maximum decreasing trend, where the slope is -10.12 mm/year. This implies that monsoon is becoming drier over time in Rajshahi.

- In Chittagong, decreasing Lower Confidence Level of rainfall and increasing Upper Confidence Level of temperature give the evidence of increasing possibility of drought during winter.

- On the other hand, in Dhaka, possibility of drought during post-monsoon has become the least due to increasing trend of rainfall LCL and decreasing trend of temperature UCL.

Potential Adaptation Measures

- The study reveals that the dryness pattern has become variable throughout the country, though in different scales in different locations.

- Special concentration should be given to the drought prone agricultural land.

- Adaptation strategies can include:
- Strategies for adaptation need to be developed and implemented in a flexible way, in order to take into account further progress of scientific knowledge.

- The regions or areas, showing decreasing trend in monsoon rainfall, should get proper and careful consideration from agricultural point of view.

Recommendations for Future Research

- Correlation between temperature and rainfall changes can be analyzed for drought assessment in Bangladesh

- Comparison can be delineated among existing drought indices (developed in climatic conditions different from Bangladesh) and developed drought indices in this study.

- Analysis can be performed to identify whether there is any specific drought movement path/locus over the country, The trend of drought movement path can be used as important information for drought warning system in the country.

- Drought damage matrices can be developed for several drought affected sectors.

- Drought damages can be quantified and expressed in economic terms with the help of the drought damage cause factors developed in this study.

Conclusion

- The study develops methods for spatio-temporal assessment of meteorological drought in Bangladesh.
- The dryness and drought patterns in Bangladesh is variable.
- The probability of drought ranges from moderate to high in the country.
- Drought damage curves as well as drought damage cause factors have been developed to address the drought damage.

Thank you

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