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Standardized precipitation evapotranspiration index (SPEI) based drought assessment in Bangladesh

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Abstract

Drought is a natural phenomenon. It has negative impact on agriculture, ecosystem and livelihood. Standardized Precipitation–Evapotranspiration Index (SPEI) is a new drought index. It considers the rainfall and evapotranspiration to index drought. SPEIbase (model) data for 110 years (1901-2011) were utilized in the study to understand drought evolution in Bangladesh. Twenty eight (28) weather station locations of Bangladesh Metrology Department (BMD) were considered for the analysis and mapping of drought. SPEI data were classified for severe and extreme drought event. Inverse Distance Weight (IDW) method was used to interpolate the point data for spatial mapping of drought severity. It is evident that SPEI can identify drought prone area, duration, onset, extent and end. The finding shows that North-Eastern part of Bangladesh is more vulnerable to both extreme and severe drought event. SPEI can be an important tool to understand the climate change induced drought evolution and assessment in Bangladesh.

INTRODUCTION

Bangladesh has an agrarian economy. Agriculture is the primary producing sector of the economy since it comprises about 18.6% (data released on November, 2010) of the country's GDP and employs around 45% of the total work force [1]. The performance of agriculture sector has an overwhelming impact on major macroeconomic indicators like employment generation, poverty alleviation, human resource development and food security. Bangladesh achieves a position of being able to produce enough rice not only to meet its food, feed, and seed requirements, but also to be left with some exportable surplus. Yet, the agriculture sector is extremely vulnerable to disaster and climate induced risks. Climate change is anticipated to aggravate the frequency and intensity of extreme weather events in Bangladesh [2]. Drought is one of the major problems for the agriculture and its development in the country. It is a slow extermination which can last for number of days to several years with a devastating effect on the agricultural production and livelihood of the people [3]. There are some regions in Bangladesh where every steps of agriculture from field preparation to ripening of crops dependents on rainfall [4]. Consequently, drought affects annually 2.5 million ha in kharif (wet season) and 1.2 million ha in dry season [5].Therefore, drought management in agriculture is a major challenge for Bangladesh in achieving sustainable agricultural development. To tackle the drought efficiently it is essential to understand the spatial-temporal pattern of drought evolution in Bangladesh. But climate change induced drought evolution and patterns are not clear and less documented particularly in Bangladesh situation. GIS is an important tool for spatial temporal mapping to know the status of different ecosystem [6]. However, GIS based long-term drought monitoring and assessment in Bangladesh is not common. With this view, this study has been proposed. The objective of the study is to know the spatial and temporal pattern of drought in Bangladesh using long-term (historic data) data.

MATERIALS AND METHODS

Drought is an insidious natural hazard that results from lower levels of precipitations than usual. It is one of the main natural causes of agricultural, economic, and environmental damage [7-9]. Recently, a new drought index, the Standardized Precipitation–Evapotranspiration Index (SPEI), developed by Vicente-Serrano [10], and was proposed for detecting drought periods. The SPEI is based on a monthly climatic water balance (i.e., precipitation minus evapotranspiration). It can be calculated for different time scales to monitor droughts. The SPEI's main advantage over other widely used drought indices lies in its ability to identify the role of evapotranspiration and temperature variability with regard to drought assessments in the context of global warming. In this study we used the modeled SPEI data called SPEIbase. SPEI dataset at time scales between 1 and 48 months from January 1901 to December 2011 over Bangladesh were downloaded for the coordinates of Bangladesh Meteorology Department (BMD) weather stations.

Bar graph of Model SPEIbase data were prepared to understand the evolution of drought at different lag (3, 6, 12, 24 and 48 month). All the graphs were prepared using R statistical software.

SPEI graph and its spatial mapping were done to identify drought prone area, severity, duration, onset, extent and end. To estimate SPEI, long-term (110 years) SPEI base data of 28 weather stations (distributed throughout the Bangladesh) was used. For mapping of spatial extent of agricultural droughts from point data, an inverse distance weight method was used.

RESULTS

Long-term data shows a spatial temporal pattern of drought. It also gives information on past global change event related to climate change induced drought. SPEI value at different lag shows the intensity of drought related to different ecosystem eg. seasonal lag (3, 6 month lag) for agricultural drought and long-term (12, 24, 48 month lag) for hydrological drought (Figure 1). In the bar graph red color represents the drought intensity and the blue color represents the wet intensity. Bogra is a drought prone district of Northern Bangladesh. In Bogra drough intensity and frequency does not have distinct pattern in the 3 and 6 month lag due to recurrent drought in a short time. Both the intensity and frequency is bit clear for the case of 12, 24 and 48 month lag representing the hydrological drought. Intensity of drought was classified in Table.1.

Spatial temporal mapping of drought event shows (Figure 2 and 3) that North Bengal is prone to both extreme and severe drought event while Eastern part and middle of Bangladesh is less vulnerable to the drought event. It is also evident that number of severe drought event occurs more than that of extreme drought event.

Table 1. SPEI class

Range	Condition
SPEI≤-2	Extreme drought
-2<SPEI≤-1.5	Severe drought
-1.5<SPEI≤-1	Moderately drought
-1<SPEI≤1	Near Normal
1<SPEI≤1.5	Moderately wet
1.5<SPEI≤2	Severely wet
SPEI≥2	Extremely wet

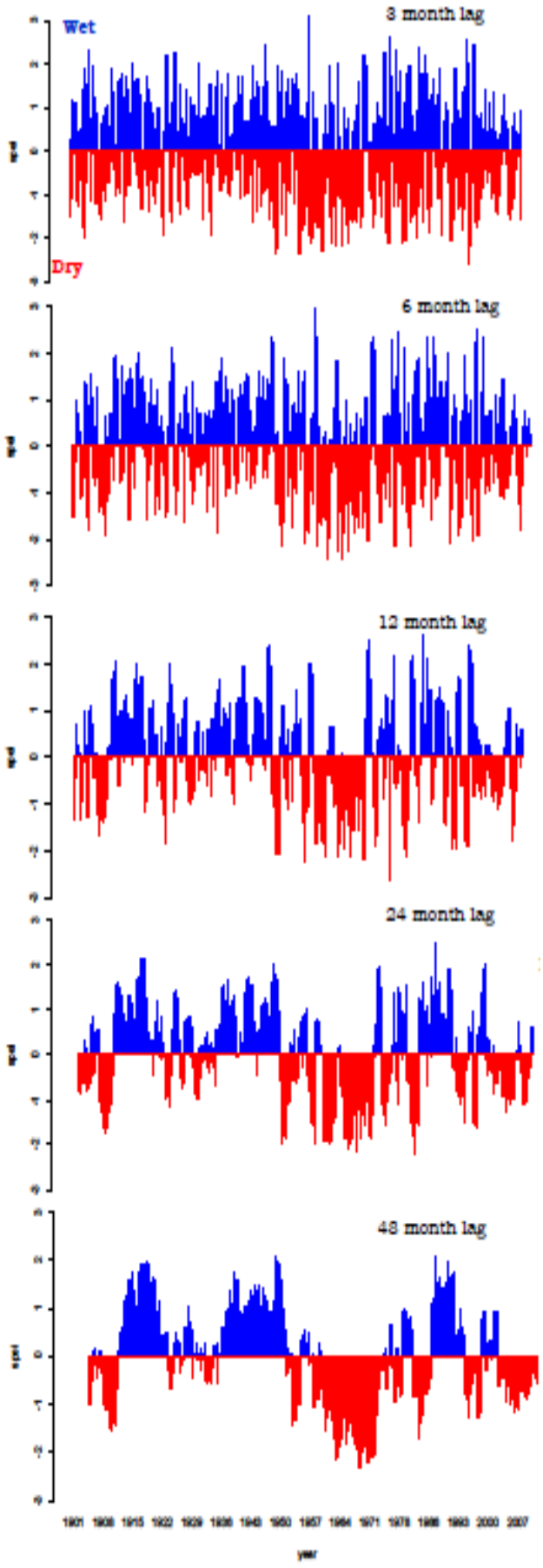

Fig. 1. Temporal evolution of the SPEI at time scales from 1 to 48 months of Bogra, a drought prone district of Bangladesh

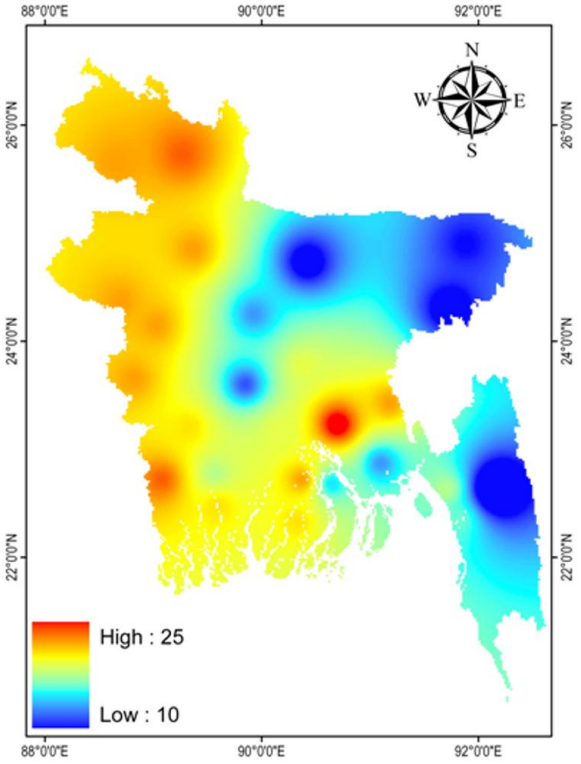

Fig. 2. No. of extreme drought event at 3 month lag

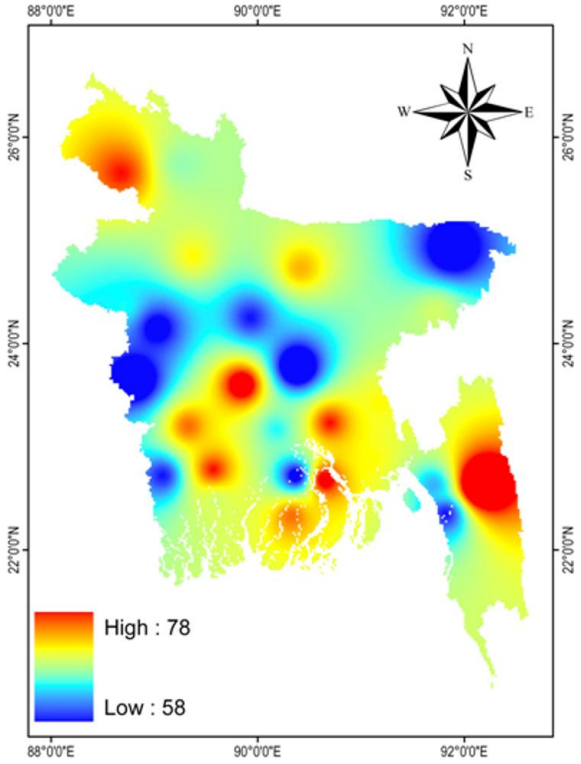

Fig. 3. No. of severe drought event at 3 month lag

DISCUSSION

Drought is a complex phenomena and it is hard to assess physically, because a short spell of rainfall can cover the severe drought in a short time, without fulfilling the actual water demand of the ecosystem. Unlike other natural disaster e.g. cyclone or earthquake, drought has a great devastating power working in hidden. Drought can be of three type's e.g. metrological drought (absence of short-term rainfall), agricultural drought (absence of short to medium-term rainfall during crop growing season) and hydrological drought

(absence of long-term rainfall). Change of global climate has impact on the climate of Bangladesh as well. The Northern part of Bangladesh is undergoing a desertification process due to cross-country anthropogenic activities (Barrage/Dams on the upstream) caused a severe negative impact on water resources and eco-systems of Bangladesh in the recent years. This might have impact on local precipitation leading to vulnerability to extreme drought event. On the other hand Eastern part of Bangladesh has wetland with regular rainfall making it less vulnerable to drought.

CONCLUSION

This study investigated the drought assessment in Bangladesh particularly spatial temporal pattern of drought using long-term data. The 0.5°gridded SPEIbase is seemed to be suitable for the detection, monitoring, and assessment of drought conditions at the regional scale. Moreover, the approach to drought characterisation based on the 0.5°gridded SPEIbase calculated for various lag periods provides comprehensive results on the complexity of drought phenomena in Bangladesh.

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