PREDICTION OF FUTURE DROUGHT IN THE NORTHWEST AND CENTRAL REGION OF BANGLADESH BASED ON PRECIS CLIMATE MODEL PROJECTIONS

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ABSTRACT
This research examines past drought and predicts future drought in selected locations of the northwest and central region of Bangladesh using two powerful and widely used drought indices namely the Standardized Precipitation Index (SPI) based on precipitation and the Standardized Precipitation and Evaporation Index (SPEI) based on both precipitation and evaporation. The analysis has been done for the observed period (1971-2014) using meteorological data and for future period (2015-2100) using data derived from PRECIS (Providing Regional Climates for Impacts Studies) climate model under emission scenario Representative Concentration Pathway 8.5 (RCP 8.5). These indices have been found to be capable of capturing historical drought events in Bangladesh and the future values indicate very frequent and severe drought events in the 21st century.

Keywords: Drought; precipitation & temperature, climate, SPI & SPEI

INTRODUCTION
Drought is one of the most damaging natural disasters. During the last 50 years, Bangladesh suffered about 20 droughts. Depending on the intensity of drought, the estimated yield reduction of different crops varies from 10% to 70% (Rahman and Biswas 1995). Apart from loss in agriculture drought has significant effect on land degradation, livestock population, fisheries, food quality and price, employment, health and society. Accurate prediction of the onset and durations of future droughts are necessary for better drought management. Previous studies indicate that both SPI and SPEI are very powerful index to detect different features of drought. But very few studies have so far been undertaken to forecast drought features in near future for Bangladesh. In this research projected climate data from PRECIS climate model will be used to forecast drought events in north-western (NW) and central region (CR) of Bangladesh.

METHODOLOGY
In the present study drought analysis were carried out in the NW (Rajshahi, Rangpur, Bogra, Dinajpur, Ishwardi)and CR**(**Dhaka, Mymensingh, Tangail**)** region using the SPI and SPEI indices computed from meteorological data. Monthly total rainfall and maximum and minimum temperature data were collected from Bangladesh Meteorological Department for the year 1971 to 2014. For forecasting future drought rainfall and temperature data were obtained from PRECIS climate model under RCP 8.5 emission scenario for the year 1971 to 2100**.**

Calculation of SPI and SPEI indices
In order to calculate SPI and SPEI, time series of precipitation and moisture deficit (P minus PET) were used, respectively. PET values were obtained from monthly maximum and minimum

temperature using Hargreaves method. These data are fitted to an appropriate probability distribution function. Two parameter gamma distribution function is used for SPI calculation and general logistic distribution function is used for calculating SPEI index in this analysis. These fitted distributions are used to calculate the cumulative probability density function for any given precipitation amount. This cumulative distribution is transformed to a standard normal distribution with a zero mean and standard deviation of unity which is the value of SPI or SPEI. Negative values of SPI or SPEI indicate dry periods while positive values indicate wet periods where a value of zero corresponds to the median precipitation. SPI values between ±0.99 are generally considered normal.

Table 1: SPI values indicate different drought conditions

2.0 or above	Extreme wet
1.5 to 1.99	Severe wet
1.49 to 1.0	Moderate wet
0.99 to -0.99	Near normal
-1.0 to -1.49	Moderate drought
-1.5 to -1.99	Severe drought
-2 or less	Extreme drought

For SPEI calculation, generalized logistic method for probability distribution and Hargreaves method for calculation of potential evapotranspiration found to be more appropriate. At first, SPI and SPEI were calculated for the year of 1971-2014 using observed data. Then SPI and SPEI were calculated for the same period using PRECIS model dataset. The distribution parameters found from this dataset were used to calculate SPI and SPEI of future period. All the drought indices are calculated for 3, 6, 9 and 12-month drought conditions.

RStudio, a programming language for statistical computing and graphics is used to compute SPEI, SPI both for controlled and future periods. In SPEI calculation, different distributions methods and different PET calculation method were applied and best fitted distribution method with PET method was chosen by trial and error that gave reasonably accurate result for observed period (1971-2014) By trial and error generalized logistic method for distribution and Hargreaves method for calculation of potential evapotranspiration were selected. Later SPI and SPEI values for future period of 2015 to 2100 were computed using those distribution parameters obtained for the observed data set.

RESULTS AND DISCUSSIONS

Future drought indices indicate very dry future and more frequent drought. It was observed that for 1971-2014 period most of the drought indices were in the range of ±1. But for future period (2015-2100) those indices are in the range of ±2 which indicates more extreme moisture deficit or surplus for future periods. Plots of 6 and 12 month SPI and SPEI computed from observed data of 1971-2014 are shown in Figure 1 and 2, respectively. SPI and SPEI of the same period (1971-2014) computed from PRECIS data are shown in Figure 3 and 4, respectively.

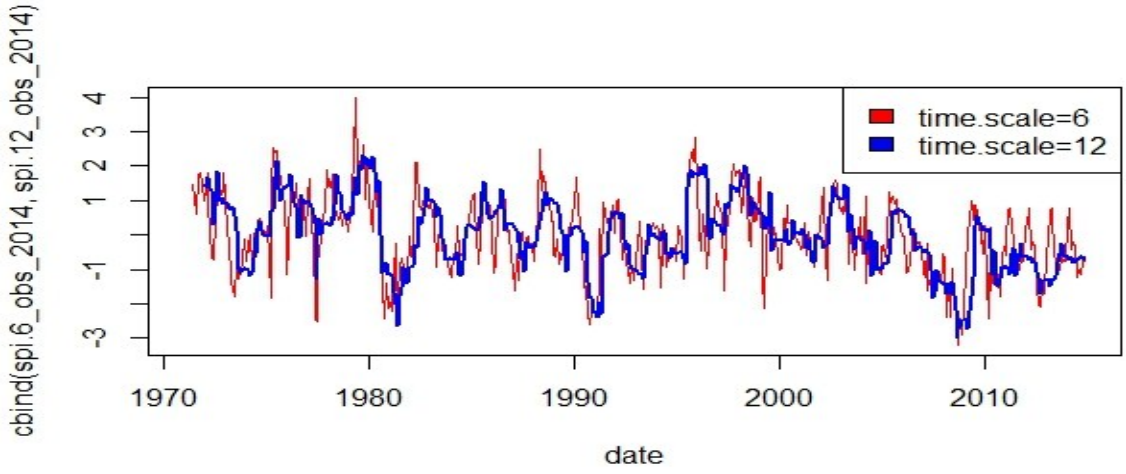

Fig. 1: Rajshahi's SPI series for observed period (1971-2014)

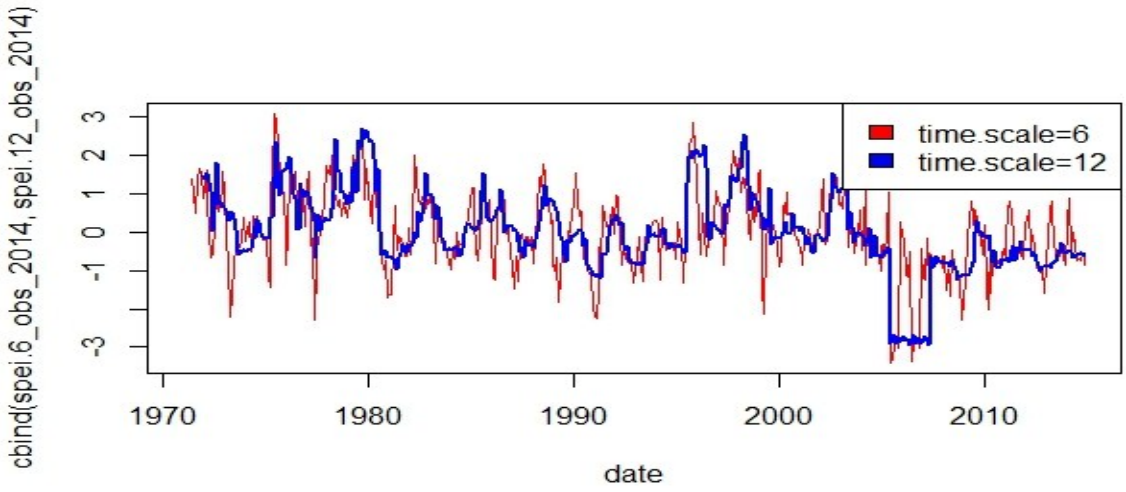

Fig. 2: Rajshahi's SPEI series for observed period (1971-2014)

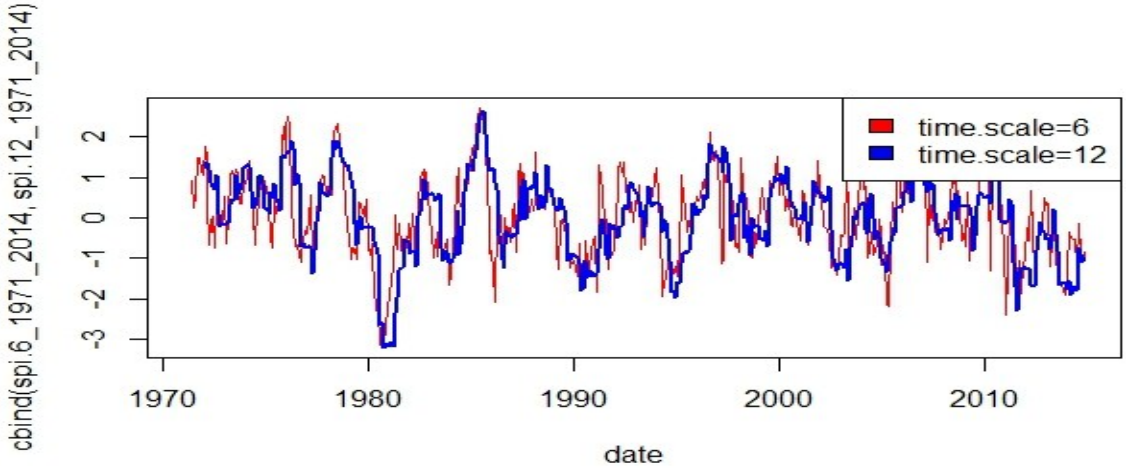

Fig. 3: Rajshahi's SPI series for 1971-2014 using PRECIS dataset

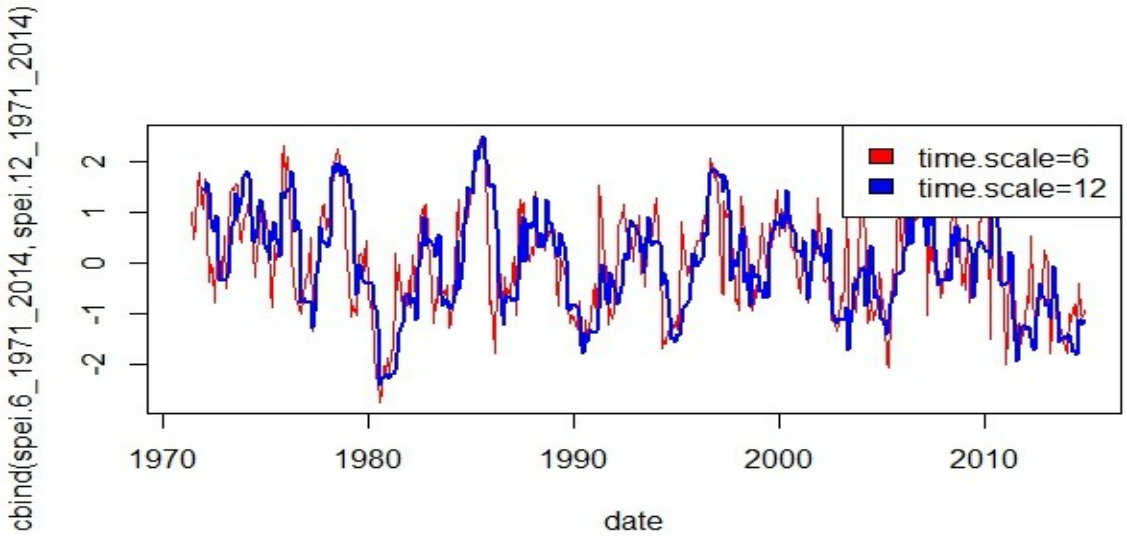

Fig. 4: Rajshahi's SPEI series for 1971-2014 using PRECIS dataset

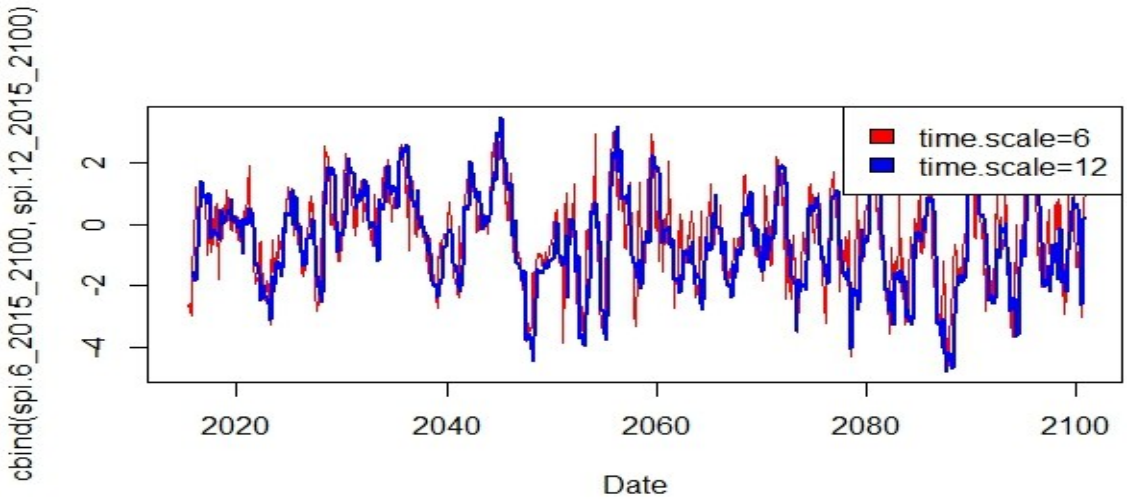

Fig. 5: Rajshahi's SPI time series for future 2015-2100

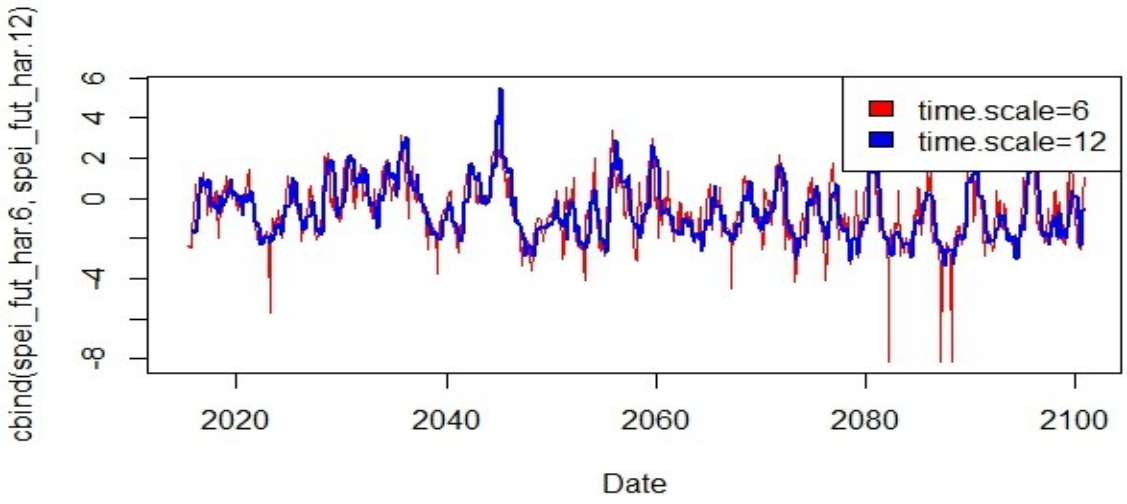

Fig. 6: Rajshahi's SPEI time series for future 2015-2100

It is observed that in future intensity of drought will increase (Figure 5 and Figure 6). The SPI series of future indicate a dry future but SPEI values indicate even more dry future. As world's temperature is increasing day by day due to the emission of greenhouse gases and SPEI depends on both temperature and precipitation, SPEI predicts drier future than SPI which depends only on precipitation. Again as the PRECIS data is for the extreme climatic scenario (RCP 805), therefore both SPI and SPEI indicate high probability of drought in future. However the drought and wet events identified from both SPI and SPEI indexes for 1971-2014 periods indicated almost similar moisture condition. Therefore the correlation between SPI and SPEI values are very high for both observed and PRECIS data for observed period.

Table 2: Correlation of SPI and SPEI for observed data and PRECIS

R^2 Values between SPI and SPEI		
DISTRICT	R^2 (observed)	R^2 (PRECIS)
Rajshahi	0.703265	0.925339
Rangpur	0.751834	0.949239
Dinajpur	0.913151	0.936289
Bogra	0.929033	0.946643
Ishwardi	0.923459	0.946503
Dhaka	0.93378	0.956655
Mymensingh	0.899391	0.948599
Tangail	0.944090	0.953664

The analysis of PRECIS model projection for 1971 to 2100 shows an increasing trend line for monthly average temperature and decreasing line for monthly total rainfall. However results also indicate few extreme rainfall events in 21st century.

Validation of result

Historical drought events record says that Bangladesh has faced some severe and moderate droughts in recent years. SPI and SPEI value from both observed and model dataset detected those drought years reasonably accurately. So this indicates that both SPI and SPEI are good indicator of drought. PRECIS monthly values and the distribution of temperature over the year are also compared with the observed temperature for year 1971-2014 and these values are matched properly.

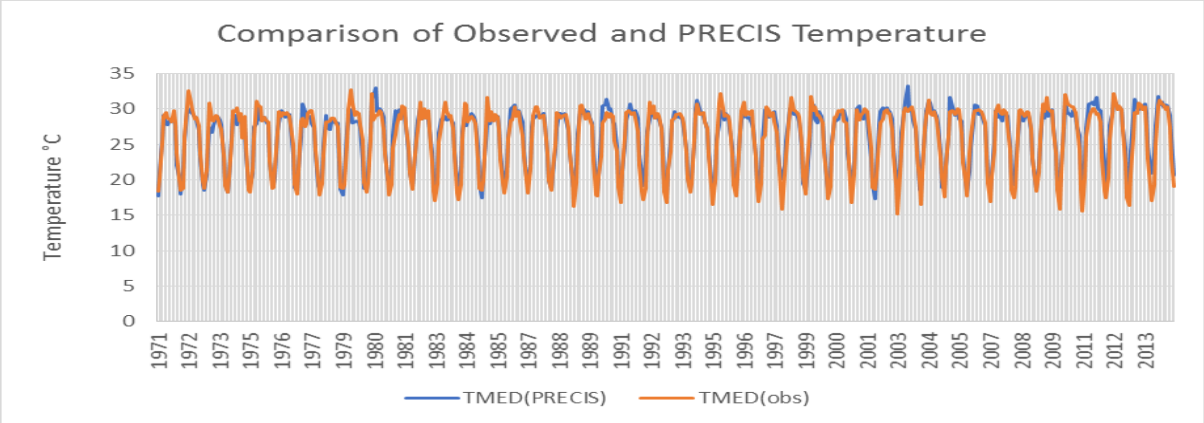

Fig. 7: Comparison of observed and PRECIS temperature for Ishwardi

Table 3: Comparison of the drought severity of Historical drought events with the drought severity obtained from the SPI and SPEI value

Historical Drought Year	SPI (Observed)	SPEI (Observed)	SPI (PRECIS)	SPEI (PRECIS)
1973	Extreme	extreme	moderate	moderate
1974	extreme	severe	moderate	moderate
1975	severe	severe	extreme	Extreme
1976	severe	severe	extreme	moderate
1979	moderate	moderate	moderate	moderate
1980	moderate	severe	extreme	extreme
1981	severe	extreme	moderate	severe
1982	severe	severe	Severe	moderate
1989	severe	severe	Severe	moderate
1992	severe	severe	Severe	severe
1994	severe	severe	Severe	extreme
1995	extreme	severe	extreme	extreme
1996	moderate	extreme	extreme	moderate
2000	extreme	severe	Severe	moderate
2009	severe	severe	moderate	moderate
2011	extreme	extreme	Severe	severe

CONCLUSIONS

The SPI and SPEI results obtained from this study indicate a very dry future with more frequent and severe drought events for PRECIS RCP 8.5 scenario. These results can provide valuable information for long-term regional and national drought risk management

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