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ANNUAL AND SEASONAL TRENDS OF PRECIPITATION IN MOULVIBAZAR DISTRICT OF BANGLADESH FROM 1950 TO 2014 USING MANN-KENDALL TEST

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Abstract

Investigating long term trend of precipitation is important for understanding the effect of climate change. The objective of this study was to document and examining the seasonal and annual trends of precipitation in Moulvibazar district of Bangladesh from daily precipitation data of Sreemangal Meteorological Station of Moulvibazar for a period of 65 years (1950-2014) using the non-parametric Mann-Kendall test. Annually, 65 years average precipitation was 2420±390 mm whereas dry season (December-March), pre-monsoon (April-May), monsoon (June-September) and post-monsoon (October-November) seasons average were 131±89 mm, 639±223 mm, 1447±276 mm and 203±111 mm, respectively. Dry season showed the most inconsistency (coefficient of variation, CV 68%) while monsoon season showed the most consistency (CV 19%) among the seasons. The findings of the non-parametric Mann-Kendall test reveal that significant decreasing trend of rainfall was only found in monsoon season time series. No significant trend was found in either annually (decreasing), dry season (decreasing), pre-monsoon season (increasing) and post-monsoon season (decreasing).

Keywords: Precipitation, trend analysis, climate change.

Introduction

Presently, the climate change triggered by global warming is posing a major threat to the resilience of agricultural systems. Increasing temperatures, changes to rainfall amount and distribution, coupled with major shifts in other meteorological parameters in comparison with long term observations have further complicated the production process. Understanding the trend of precipitation at temporal scale is important for sustainable ecological-societal system under the lens of climate-smart agriculture framework (FAO, 2013; Lipper *et al.*, 2014). Agricultural systems mainly depend on precipitation for water supply in most of the part of the world. Crop production in Moulvibazar region is also highly dependent upon amount and distribution of precipitation. In addition, still variability of big historical precipitation data is not well understood since the characteristics of precipitation vary over spatio-temporal scale.

There are some studies on precipitation over Moulvibazar district of Bangladesh. Rahman *et al.* (2008) studied effective precipitation using four different methods for the ten Meteorological Stations from south-eastern part of Bangladesh and observed that as the distance from sea increases the value of effective rainfall percentage also increases. Ahsan *et al.* (2010) investigated the variability and trends of summer monsoon rainfall over Bangladesh for 50 years (1961-2010). The study also considers the investigation of the relationship of the monsoon rainfall variability with El Nino-Southern Oscillation (ENSO) activity. The correlation analysis has also been performed between the precipitation of Bangladesh and that of Nepal and Bhutan and the nearby sub-divisional precipitation regions of India. They reported the decreasing trend of average monsoon precipitation (-0.53 mm year^{-1}) of the country as well as the eastern region (~ -2 to -7 mm year^{-1}). Roy (2013) checked annual average precipitation of 30 years (1979-2008) in Sylhet region and found the decreasing trend of monsoon average precipitation. Hasan *et al.* (2014) examined the precipitation patterns and their associated changes in Sylhet through statistical analysis of daily precipitation data during the period of 1957-2006. It has been observed that a good correlation exists between the

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monthly mean and daily maximum precipitation. A linear regression analysis of the data is found to be significant for all the months. Some key statistical parameters like the mean values of coefficient of variability, relative variability and percentage inter-annual variability have been studied and found to be at variance. Shah *et al.* (2014) analyzed monthly, yearly and seasonal variations of dry days and associated changes from daily records of 54 years (1957-2010) for Sylhet region using the Fast Fourier Transform (FFT). They found almost every year there was a peak dry event and the major dry events was slightly earlier in a year compare to the previous year. Rahman *et al.* (2015) studied the annual patterns of precipitation during 1957-2012 in Sylhet district using the non-parametric Mann-Kendall test and found no significant trend of rainfall. However, the above studies are mostly concentrated on annual trend and are subject to further confirmation through more detail study by analyzing at seasonal scale. Therefore, the present study focuses on the temporal (inter-seasonal and inter-annual) variability and trends of precipitation in more details in Moulvibazar district using long time series data sets covering 65 years (1950-2014). The analysis will improve the general understanding of the seasonal and annual precipitation variability and trends over Moulvibazar district of Bangladesh.

Materials and Methods

Study site: Sreemangal (24.30º N, 91.73º E, 21.95 m above msl) of Moulvibazar district of Bangladesh under the North-East Hydrological Region of Bangladesh (WARPO, 2001) was selected for this study. This region is an interesting study area because of its diversified terrestrial and wetland ecosystems.

Meteorological data collection: Daily precipitation (mm) of Sreemangal of Moulvibazer district for a period of 65 years (1950–2014) was collected from the Bangladesh Meteorological Department (BMD). BMD follows the World Meteorological Organization (WMO) regulations for quality control of data. From the meteorological point of view, there are four climatic seasons in Bangladesh. They are: Dry (December-March), Pre-monsoon (April-May), Monsoon (June-September) and Post-monsoon (October-November). It may be noted here that for the computation of seasonal values for the dry season, the data of December for one year has been used with the data of January, February and March of the following year to represent the dry season values of the following year.

Statistical analysis: Seasonal and annual means, standard deviation and coefficient of variation were calculated from 1955 to 2014. The normal was defined as the average for the period from 1955 to 2014 in this article. Trends of annual and seasonal rainfall data were analyzed by Non-parametric Mann-Kendall (M-K) test (Mann, 1945; Kendall, 1975; Helsel and Hirsch, 2002) using the R statistical package. Before applying the Mann-Kendall test to the time series of annual and seasonal precipitation time series, presence of serial correlation was investigated by examining the autocorrelation (ACF) and partial autocorrelation (PACF) plots produced by R whether the annual precipitation levels are serially correlated. If most of the vertical spikes in the ACF and Partial ACF plots produced by R fall within the horizontal band defined by the blue dotted lines beyond which autocorrelations and partial autocorrelations would be deemed to be significant. In this study, ACF and PACF were found insignificant. Therefore, the Mann-Kendall test was applied as it is without corrects the P-value with block bootstrapping protocol. The presence of serial correlation among the time series can be investigated visually with the help of the ACF and PACF functions in R, which compute the autocorrelation and partial autocorrelation corresponding to the time series of annual and seasonal precipitation. The output of this test produced by R was reported the Kandall's tau statistic and the 2-sided P-value for testing the hypotheses "Ho: no trend" versus "Ha: monotonic trend (upward or downward)".

Results and Discussion

Precipitation provides natural source of water for agricultural ecosystem in Moulvibazar region. Annual profile of the Moulvibazar station mean monthly precipitation of Bangladesh shows a unimodal pattern with high precipitation in monsoon season with highest in May-June and low precipitation between November-February with lowest in January (Fig. 1). Talucder *et al*. (2015) also found similar findings in Sylhet district of Bangladesh.

Fig. 2 shows the annual precipitation trend of Moulvibazar for 65 years of the period 1950-2014. Annual normal, standard deviation and coefficient of variation were 2420 mm, 390 mm and 16%, respectively from 65 years period (1950-2014). It indicated that the 31 years annual precipitation was above the normal (i.e. 2420 mm) while 34 years annual precipitation was below the normal. Among the study period time series, precipitation (3565 mm) of the

year 1976 was highest while the year 1992 precipitation (1741 mm) was lowest. Kendall's tau statistic was -0.135 and two-sided P-value 0.11422 which indicates Mann-Kendall test is statistically insignificant, suggesting the presence of a statistically insignificant decreasing trend in the annual precipitation time series. The observed annual precipitation trend in our study is well within the reported from other studies in the literature for this region. For example, Rahman *et al*. (2015) reported no significant trend in the time series of precipitation at annual scale in nearby Sylhet district using the non-parametric Mann-Kendall test.

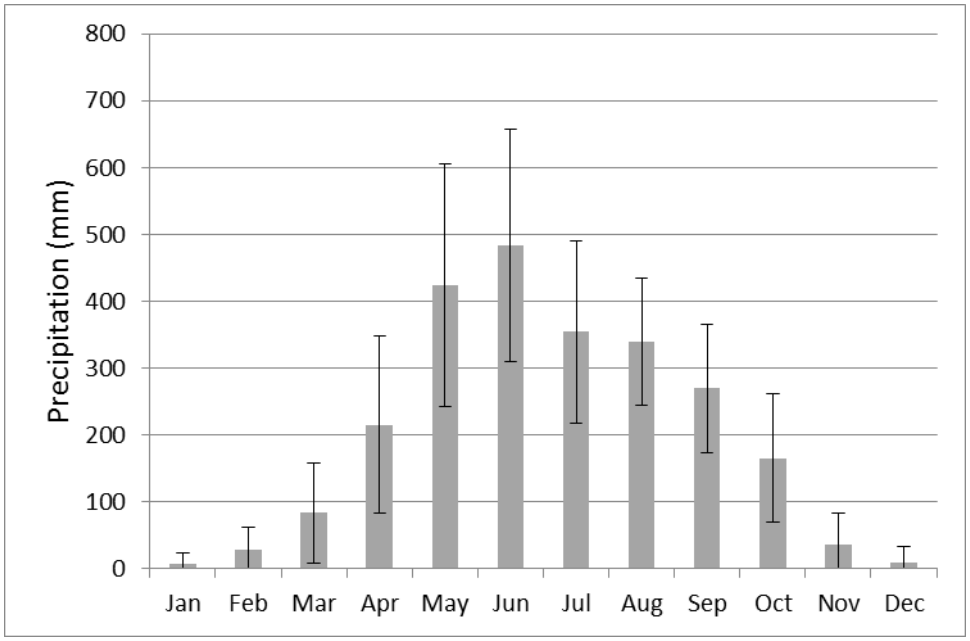

Fig. 1. Monthly mean with standard deviation from the periods of 65 years (1950-2014).

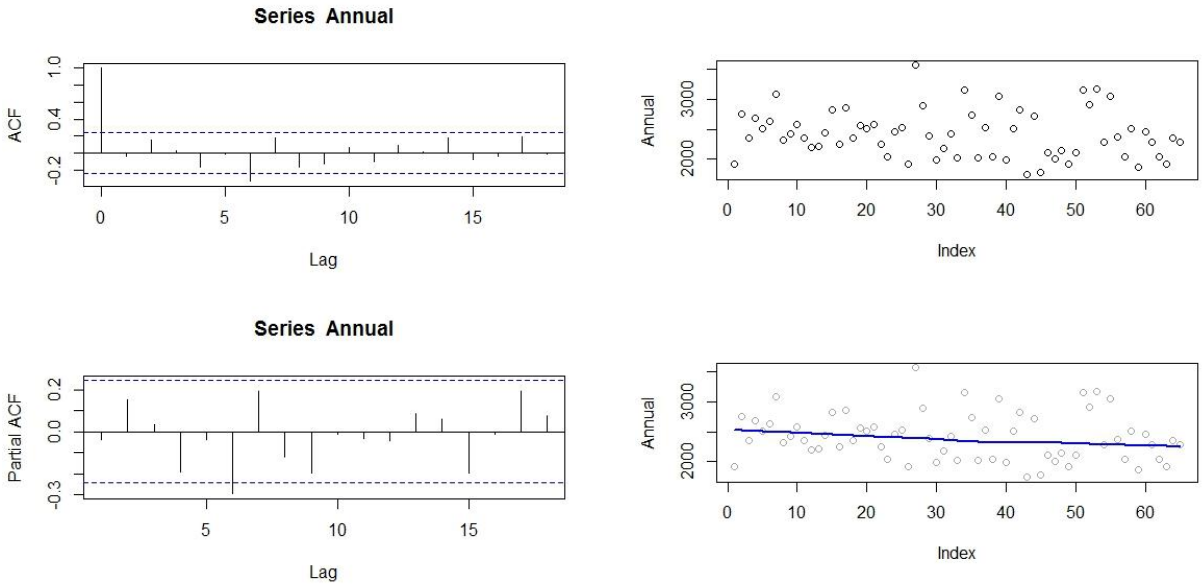

Fig. 2. Autocorrelation (ACF) and partial autocorrelation (PACF) (left); and trend (right) of precipitation at annual scale during the period of 1950-2014.

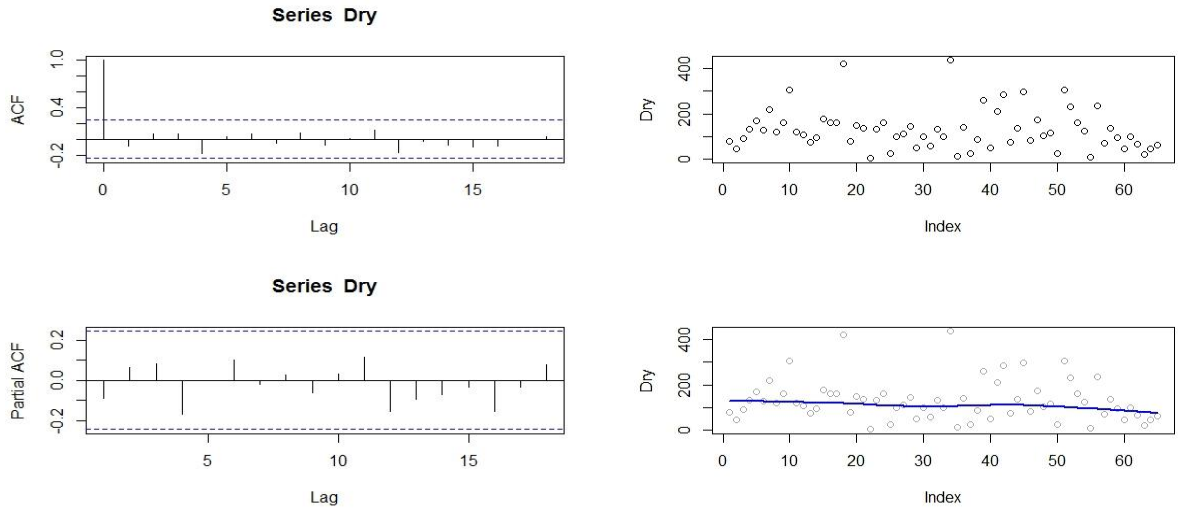

Fig. 3. Autocorrelation (ACF) and partial autocorrelation (PACF) (left); and trend (right) of precipitation at dry season during the period of 1950-2014.

Fig. 3 shows the dry season (December-March) precipitation trend from 1950-2014. Mean dry season precipitation was 131±89 mm. It showed most inconsistency (CV 68%) among the years. The highest (435 mm) and the lowest (4 mm) dry season precipitation happened in year 1983 and 1971, respectively. That mean dry season was almost precipitation less. Kendall's tau statistic was -0.123 and two-sided P-value was 0.14879 which indicates Mann-Kendall test is statistically insignificant, suggesting the presence of a statistically insignificant decreasing trend in the dry seasonal precipitation time series.

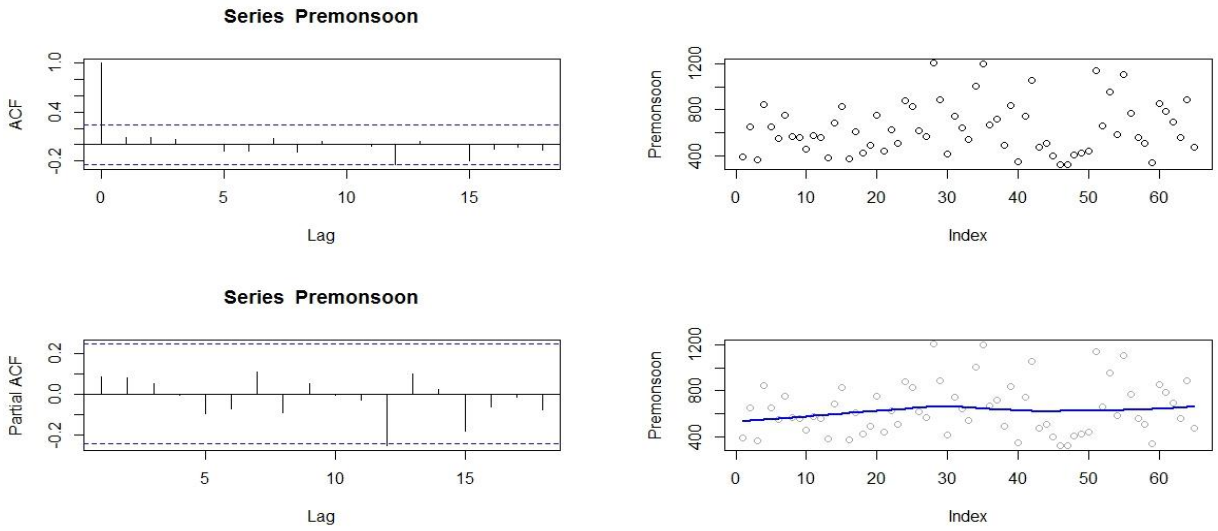

Fig. 4. Autocorrelation (ACF) and partial autocorrelation (PACF) (left); and trend (right) of precipitation at pre-monsoon season during the period of 1950-2014.

Fig. 4 shows the pre-monsoon season (April-May) precipitation trend. Mean pre-monsoon season precipitation was 639±223 mm with a coefficient of variation was 35%. The highest and lowest pre-monsoon season precipitation was found in 1977 (1205 mm) and in 1995 (318 mm), respectively. Kendall's tau statistic was 0.0664 and two-sided P-value was 0.43796 which indicates Mann-Kendall test is statistically insignificant, suggesting the presence of a statistically insignificant increasing trend in the pre-monsoon seasonal precipitation time series.

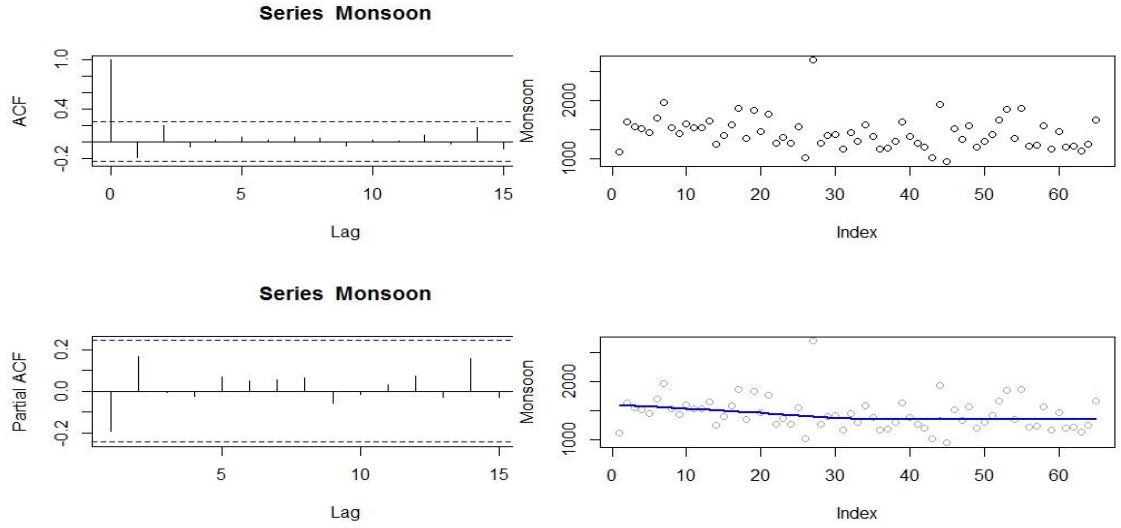

Fig. 5. Autocorrelation (ACF) and partial autocorrelation (PACF) (left); and trend (right) of precipitation at monsoon season during the period of 1950-2014.

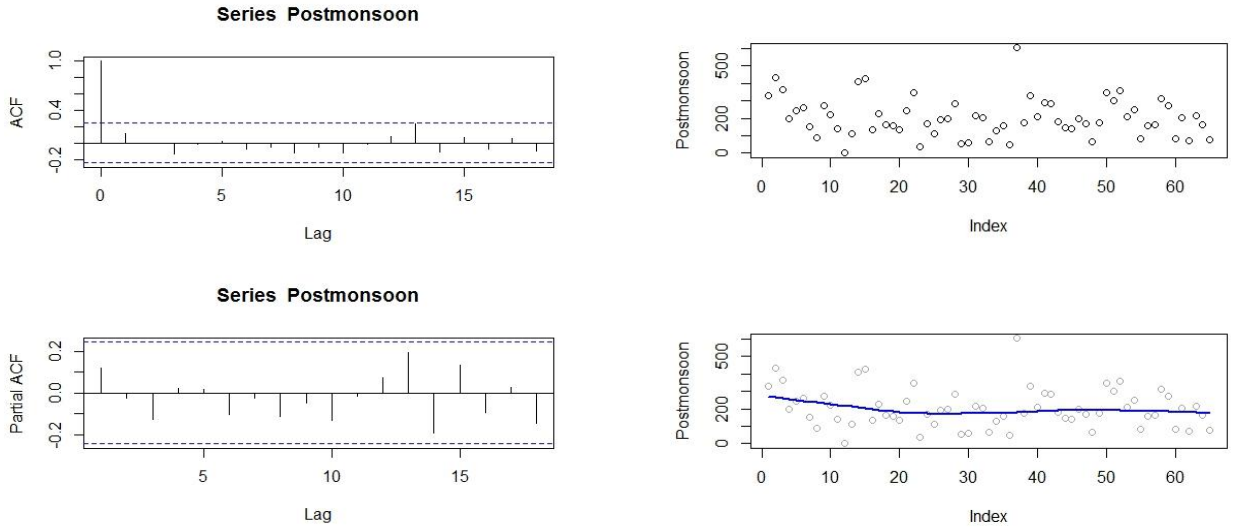

Fig. 6. Autocorrelation (ACF) and partial autocorrelation (PACF) (left); and trend (right) of precipitation at post-monsoon season during the period of 1950-2014.

Fig. 6 shows the post-monsoon season (October-November) precipitation trend. Mean post-monsoon season precipitation was 203±111 mm with a coefficient of variation 55%. The highest (602 mm) and lowest (0 mm) post-monsoon season precipitation was found in 1986 and 1961, respectively. Kendall's tau statistic was -0.0673 and two-

sided P-value was 0.43131 which indicates Mann-Kendall test is statistically insignificant, suggesting the presence of a statistically insignificant decreasing trend in the post-monsoon season precipitation time series.

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