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Change Detection of Annual Temperature and Rainfall in Kalimpong Station under Hill Zone of West Bengal

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ABSTRACT

Detecting the trend of temperature and rainfall change can help in assessing crop water availability, groundwater recharge and future climatic scenario. Considering the importance, the current paper aims at detecting the annual temperature and rainfall trend through Mann Kendall test and to evaluate the variation of Standardized Precipitation Index (SPI) values over years. The Mann Kendall test has been used to detect the climatological trend of the Kalimpong station, situated in the Hill zone of West Bengal. To determine the drought and wet situation over years, the Standardized Precipitation Index is used. The result reveals that the minimum temperature and rainfall show increasing trend and maximum temperature shows decreasing trend. The SPI values over years indicate that extremely wet and extremely dry weather condition occurs after 1980s. From this period the rainfall fluctuations also shows higher magnitude. The effect of global warming is present in the hill zone of West Bengal.

1. Introduction

There is a close relationship between agriculture and weather. Indian agriculture is largely dependent on rainfall and water availability through irrigation. The recent changes in rainfall pattern and variation of its intensity create an uncertainty in agricultural production system (Dash *et al.*, 2007). There is a change in temperature pattern also due to global warming. The temperature shows a rising trend at most of the stations in South, Central and Western parts of India (Jain and Kumar, 2012). Temperature and its changes influence the crop growth and hydrological processes. So, there is a need to detect the changing trend of temperature and rainfall in view of crop water availability, ground water recharge and many other purposes. Moreover, the trend analysis of climatic variables can help in construction of future climate scenario (Pal and Al-Tabbaa, 2010).

Hence, several scientists worked on station-wise rainfall and temperature trend analysis (Rupakumar *et al.*, 1992; Guhathakurta and Rajeevan, 2008; Subash *et al.*, 2010). Literature survey indicated very less work has been carried out for the hilly tracts of West Bengal in this regard. Hence, the current paper aims at detecting the annual temperature and rainfall trend through Mann Kendall test and to evaluate the variation of SPI values over years.

2. Materials and methods

Study location: Kalimpong Station (27.06^0 N, 88.47^0 E) has been chosen to carry out the present work. The station is situated in the Hill Zone of West Bengal. The zone mainly comprises three popular places, namely, Darjeeling, Kalimpong and Kurseong. Kalimpong subdivision consists of Kalimpong Municipality and three community development blocks (Kalimpong-I, Kalimpong-II and Gorubathan. The three blocks contain 42 *gram panchayats*.

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Summers are mild and monsoons are severe, often causing landslides causing great transportation problems. Acacia is the most commonly found species at lower altitudes, while cinnamon, ficus, bamboo, cactiand cardamom, are found in the hillsides around Kalimpong. The highest point in Kalimpong, has an altitude of 1704 m and the forests found at higher altitudes are made up of pine trees and other evergreen alpine vegetation.

Collection of weather data: The weather data of Kalimpong station was collected from India Meteorological Department. The data for 57 years (1942 to 2002) was used for the trend analysis and evaluating SPI values.

Trend analysis: Initially the yearly data of weather parameters were plotted and simple trend analysis was carried out. The trend of five years moving average of temperature data is also worked out. Lastly the Mann Kendall test was applied to detect the temperature and rainfall trend for eight years period. Mann Kendall test is a statistical test widely used for the analysis of trend in climatologic (Mavromatis and Stathis, 2011) and in hydrologic time series (Yue and Wang, 2004). There are two advantages of using this test. First, it is a non-parametric test and does not require the data to be normally distributed. Second, the test has low sensitivity to abrupt breaks due to inhomogeneous time series. Indiana Department Environmental Management (IDEM) has developed a spreadsheet for Mann-Kendall test, which is used in the present study (Davidstatistics, 2015).

Standardized Precipitation Index (SPI): The SPI calculation for any location is based on the long-term precipitation record that is fitted to a probability distribution, which is then transformed into a normal distribution so that the mean SPI for the location and desired period is zero (Edwards and McKee, 1997). A drought event occurs any time the SPI is continuously negative and reaches intensity of -1.0 or less. The event ends when the SPI becomes positive. The SPI is calculated using the following equation:

$SPI=(X_{ij} - X_{im}) / \sigma$

Where, X_{ij} is the seasonal precipitation ith station and jth year. X_{im} is the long term seasonal means and σ is its Standard Deviation.

3. Result and discussion

Variation of temperature and rainfall: The variations of annual temperature (maximum, minimum and mean temperature) of Kalimpong Station are presented in Fig. 1.

The trend of minimum temperature shows prominent increase, while the trend of maximum temperature slightly decreases. However, the trend of mean temperature shows increasing trend (this trend line is sown in figure). The maximum temperature shows a peak during 1992 and afterwards it decreases steeply. The opposite trend is observed for minimum temperature. Hence during 1992, the annual temperature range shows maximum value (20^0C) which may be due to presence of more numbers of cloudless days. In this year, the less amount of rainfall confirms the situation. The mean temperature shows an increasing trend and the trend line drawn through the mean temperature change gives following equation:

$Y = 0.027*x + 16.21$ (R^2=0.33, N=55)

Where, Y = Mean temperature, x = Year numbers.

So, the rate of increase of mean temperature is 0.027^0C per year. The 5 years moving average also shows increasing trend of mean temperature (Fig. 2). From 1944 to 1955, the five years average of mean temperature fluctuates between 16 to 16.5^0C, after which it increases steadily up to 18.5^0C during 1960-62. Then there is a fall of average temperature up to 1970 till mean temperature touches 16^0C. But after 1985, the five years moving average never falls below 17^0C. Thus a shifting of temperature is indicated through this study. The variation of rainfall shows slightly increasing trend during the study period (Fig. 3). Up to 1975-76, the fluctuation of annual rainfall is less, afterwards which is higher. The impact climate change also suggests the enhancement of rainfall fluctuations over years (IPCC, 2013).

Periodic trend analysis: The whole study period is divided into seven periods (eight consecutive years per period) and the trend analysis has been carried out using Mann Kendall test. The test reveals that the maximum temperature shows no trend up to 1973, afterwards it shows a decreasing trend for two periods (for 1974-1983 and 1994-2001). The minimum temperature shows increasing trend during the same two periods (Table 1). The periodic trend of rainfall does not show any definite pattern, periodically it increases or decreases or no trend has been observed. However, for the whole study period, the minimum temperature and rainfall show increasing trend and the maximum temperature shows decreasing trend.

Variation of SPI: The change of SPI over years (Fig. 4) reveals a remarkable pattern related to climate change. Before 1980, the SPI never crossed +2 or -2 values. It indicates extremely wet or extremely dry weather conditions are not observed before 80's. So, extreme weather conditions are occurred more recently in the Hill Zone of West Bengal.

SPI is also a good indicator of drought occurrence. The Table 2 shows that drought occurrence is lesser than the wet-years in the study zone.

Table 1. Mann-Kendall Trend for different periods

Period	Maximum temperature	Minimum temperature	Rainfall
1942-1949	No Trend	No Trend	Increasing
1950-1957	No Trend	No Trend	Decreasing
1958-1965	No Trend	No Trend	No Trend
1966-1973	No Trend	No Trend	Decreasing
1974-1984*	Decreasing	Increasing	No Trend
1985-1993*	No Trend	No Trend	No Trend
1994-2001	Decreasing	Increasing	No Trend

*Missing data within these periods, hence the periods are more than eight years

Table 2. SPI values for different years in the Hill Zone of West Bengal

SPI Values	Dry/ Wet conditions	Year of occurrence
2.0+	Extremely wet	1984, 1993
1.5 to 1.99	Very wet	1950, 1966, 1991, 1994, 1999
1.0 to 1.49	Moderately wet	1949, 1985
-.99 to .99	Near normal	1942 to 1948, 1951 to 1964, 1967 to 1978, 1981,1983, 1987, 1992, 1995 to 1998, 2000 to 2002
-1.0 to -1.49	Moderately dry	1986, 1990
-1.5 to -1.99	Severely dry	1965
-2 and less	Extremely dry	1980, 1988

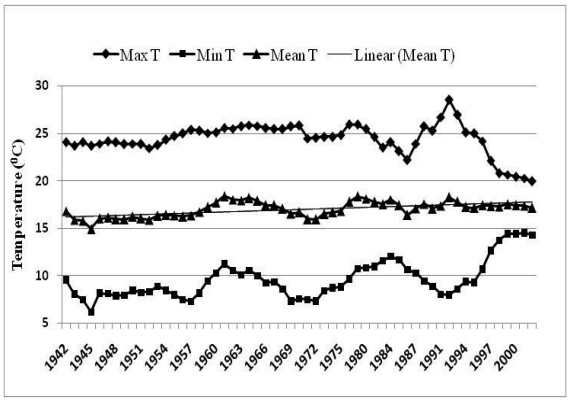

Figure 1. Variation of maximum, minimum and mean temperature over years in Kalimpong, West Bengal

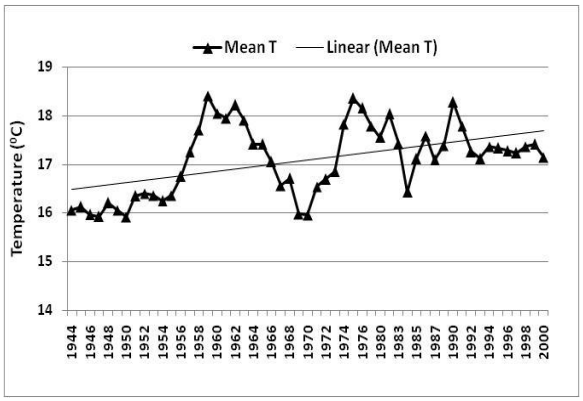

Figure 2. Five-years moving average of mean temperature over years in Kalimpong, West Bengal

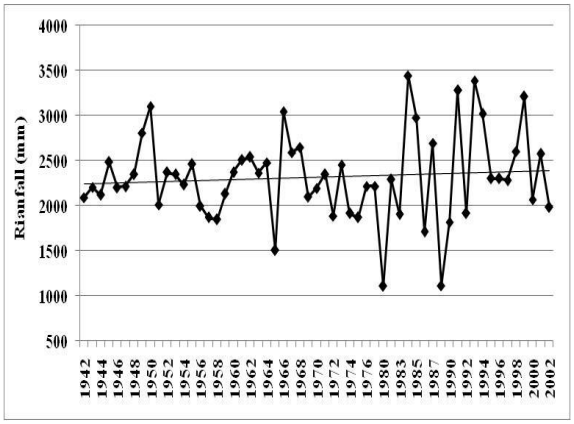

Figure 3. Variation of rainfall over years at Kalimpong Station

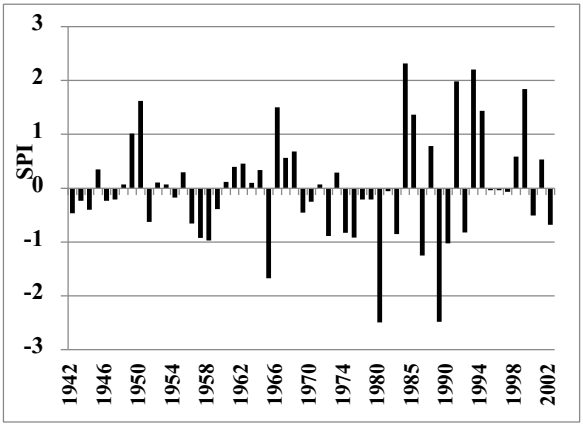

Figure 4. The change of SPI values over years at Kalimpong Station

Conclusions

It can be concluded that the maximum temperature shows decreasing trend, while the minimum temperature shows increasing trend. The mean temperature of the study area shows an increasing trend over years. The annual rainfall of the zone slightly increases over years. The extreme weather events (mainly rainfall fluctuation) increases in more recent years (after 1980). Overall the present research work gives indication of climate change in the Hill Zone of West Bengal.

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