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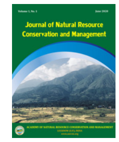

Analysis of annual rainfall and temperature trend by using the Mann-Kendall Test of Kohima Station, Nagaland, India

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ABSTRACT

Monitoring the rainfall pattern and temperature change can aid with future climatic scenarios, groundwater recharge, and crop water availability. Considering the significance, the current paper seeks to investigate the variation in Standardized Precipitation Index (SPI) values across years and to detect the annual rainfall and temperature trend using the Mann-Kendall test. The climatological trend has been identified using the Mann-Kendall test of Kohima station. The Standardized Precipitation Index is used to assess the extent of the drought and wet conditions over the years. The results showed that the maximum temperature increased up to 2014, after which there was no trend (2015-2020), and the minimum temperature decreased for three periods (1988-1996, 2003-2008, and 2009-2014). The other two periods show no trend. The change of SPI over the years shows a pattern related to climate change. Severely dry weather conditions were indicated in 1985. From 1991 to 2020, the variation of SPI value was recorded from -1.5 to -1.99. It ranged between moderately dry or wet to near normal weather conditions. Based on the above data, draught analysis provides information about a station's history of droughts.

Keywords: Rainfall trend, temperature trend, climate change, Mann-Kendall, SPI

INTRODUCTION

A close link exists between weather and agriculture. Water availability for irrigation and rainfall are two significant factors affecting Indian agriculture. The agriculture production system is still being determined due to the recent variations in rainfall patterns and intensity (Dash *et al.*, 2007). The trend of temperature has evolved as a consequence of global warming. Most of the locations in South, Western, and Central India show an increasing trend in temperature (Jain & Kumar, 2012). Therefore, it is necessary to detect shifting trends in rainfall and temperature to assess crop water availability, groundwater recharge, and many other aspects.

Furthermore, climatic variable trend research can aid in creating projected climate scenarios (Pal & Al-Tabbaa, 2010). Hence, several researchers analyzed temperature and rainfall trends at various stations (Ankegowda *et al.*, 2010; Jain *et al.*, 2013; Kachaje *et al.*, 2016; Wua *et al.*, 2017; Bora *et al.*, 2022; Pawar *et al.*, 2023; Kumar *et al.*, 202). Moreover, no such study has been conducted by the researchers so far in the hilly area of the Kohima district. Therefore, using the Mann-Kendall test, the current study was undertaken to assess the variability of SPI values across the years and to detect the annual rainfall and temperature trends.

MATERIALS AND METHODS

Study location

The present work has been carried out in the jurisdiction of Kohima Station, having a latitude of 25.67° N and a longitude of 94.12° E (Figure 1). It covers a total geographical area of 1595 sq. km with an elevation of 1261 meters. Kohima is a hilly district of Nagaland, which shares its border with the Assam State and Dimapur District in the West, Manipur State and Peren District in the South, Phek District in the East, and Wokha District in the North.

The station falls under one agro-climatic zone, the Mild Tropical Hill Zone. It features a pleasant and moderate climate – not too cold in winter and pleasant in summer. It receives South West monsoon rain in summer and North East monsoon rain in winter with an average rainfall of 1500-2000mm. The major crops grown include paddy (TRC/Jhum), potato, ginger, maize, and soybean.

Collection of Meteorological data

The meteorological data for Kohima station was collected from the Soil and Water Conservation

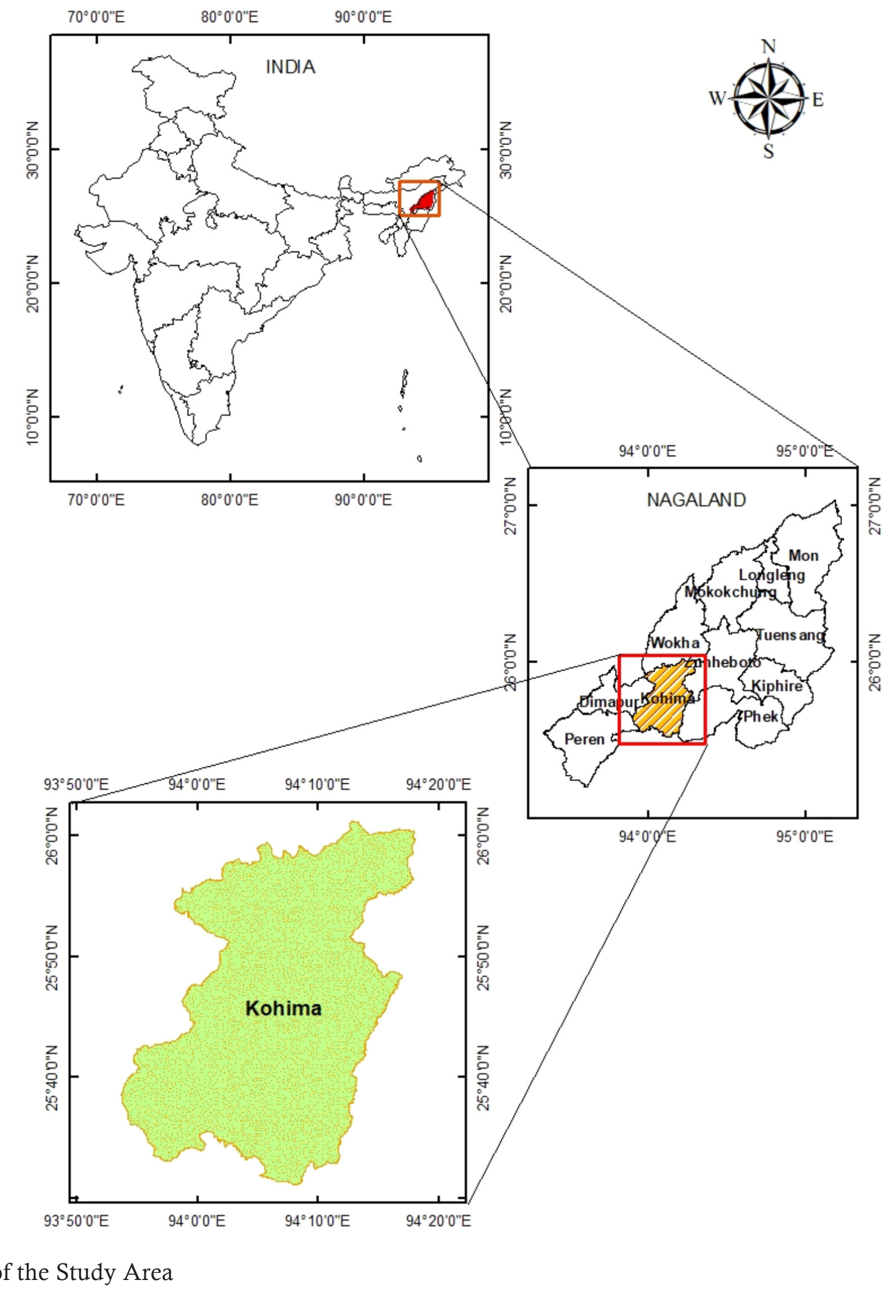

Fig. 1. Location of the Study Area

Department of the Government of Nagaland. The rainfall data from 1981 to 2020 and temperature data from 1988 to 2020 were used for the trend analysis and evaluation of SPI values.

Trend analysis: The first step was to plot the yearly data for the weather parameters and do a simple linear trend analysis. The trend of the temperature data's five-year moving average is also analyzed. The Mann-Kendall test was then used to determine the temperature and rainfall trends over eight years. Mann-Kendall test for the detection of trends (Mann, 1945; Kendall, 1975) is mainly used as a non-parametric test for statistical evaluation of the significance of monotonic increasing or decreasing trends in any hydro-meteorological time series (Yue & Wang, 2004). The use of this test has two essential benefits. Firstly, its non-parametric nature means it is not dependent on normally distributed data. Secondly, because of the inhomogeneity of the time series, the test has a low susceptibility to short gaps. The test has been performed using the Rstudio software in the present study.

Standard Precipitation Index (SPI)

The SPI is a relatively easy-to-calculate index developed by McKee *et al*. (1993) based on the likelihood of rainfall during the time scale of interest. The time frame considers how drought has affected the availability of various water resources. A long-term rainfall series for the desired period is used to calculate SPI for any location. This long-term precipitation record is fitted to a probability distribution and then converted into a standardized normal distribution to achieve a mean SPI for the area, and its desired period is zero. The positive SPI value indicates greater than median rainfall, and negative values show less than median rainfall. The SPI is calculated using the equation given:

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

Where, X_{ij} is the seasonal precipitation i^{th} station and j^{th} year.

X_{im} is the long-term seasonal means, and σ is its Standard Deviation.

RESULTS AND DISCUSSION

Variations of temperature and rainfall

Kohima Station's annual temperatures (maximum, mean, and minimum) are presented in Figure 2. The maximum temperature trend continually increases while the minimum temperature decreases. Also, the mean temperature shows a decreasing trend (the trend line is shown in the figure). The maximum temperature was observed in 2017, which shows a value of 23.8°C, and the minimum temperature shows a downfall in 2015, which shows a value of 11°C. The trend line drawn through the mean temperature changes and gives the equation as follows:

$$Y = -0.0058*x + 17.967 \ (R^2 = 0.013, N = 33)$$

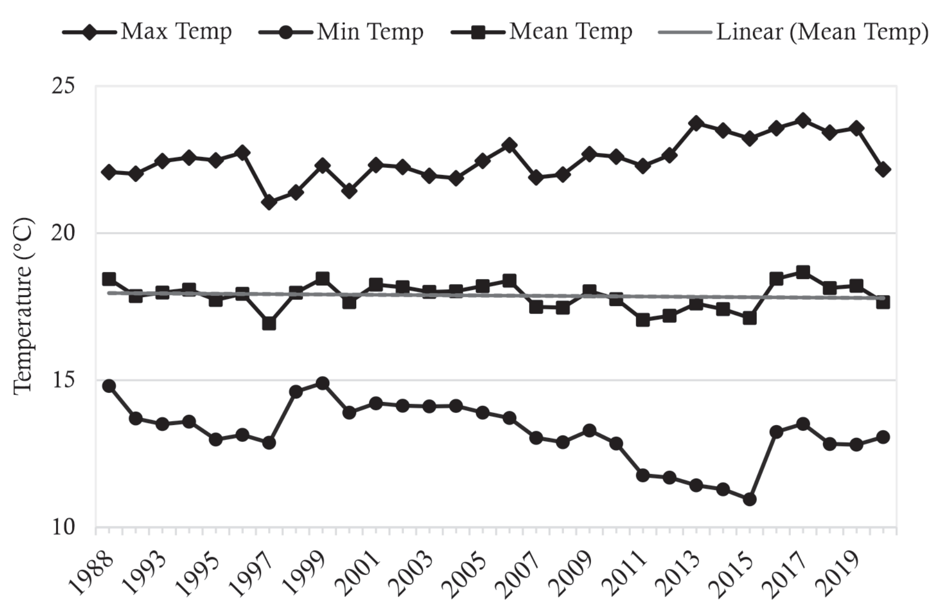

Fig. 2. Variation of minimum, mean and maximum temperature over years in Kohima

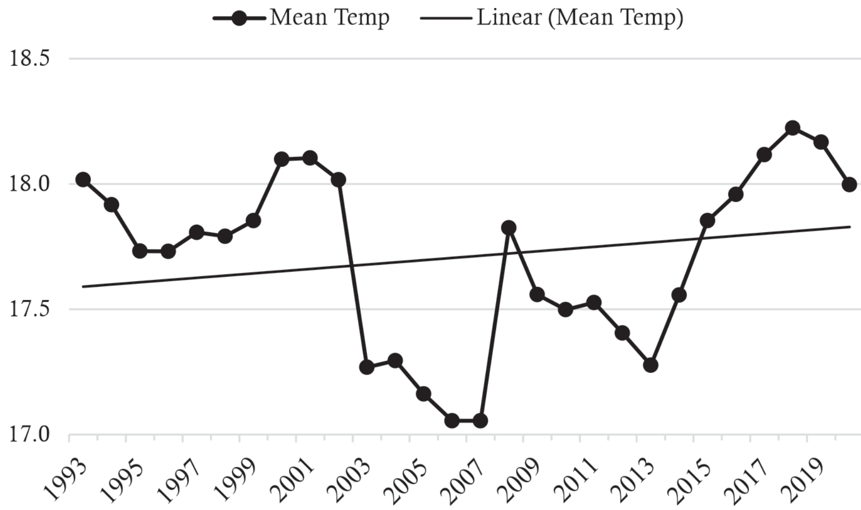

Fig. 3. Five-years moving average of mean temperature over years in Kohima

Therefore, the mean temperature decreases by -0.0058°C per year. The five-year moving average shows an increasing mean temperature trend (Figure 3). From 1993 to 2002, the five-year average mean temperature fluctuated between 17.5 to 18°C, and there was a fall in average temperature up to 2007 till the mean temperature reached 17°C. However, after 2015, the five-year moving average never fell below 17.5°C. Thus, a slight shift in temperature is indicated in this study. The rainfall variation shows an increasing trend during the study period (Figure 4). There was a fall in annual rainfall in the year 1985, which was higher. The effects of climate change also indicate a rise in rainfall variability over time (IPCC, 2013).

Periodic trend analysis

The study period for rainfall and temperature is divided into five periods, with eight and six consecutive years per period, respectively. The examination reveals that the maximum temperature showed an increasing trend up to 2014, after which it showed no trend (2015-2020). The minimum temperature decreases for three periods (1988-1996, 2003-2008, and 2009-2014), and the other two periods show no trend. The periodic trend of rainfall shows an increasing and decreasing trend, including no trend in the last period (2013-2020). From the whole study period, the minimum temperature decreases, the maximum temperature shows a

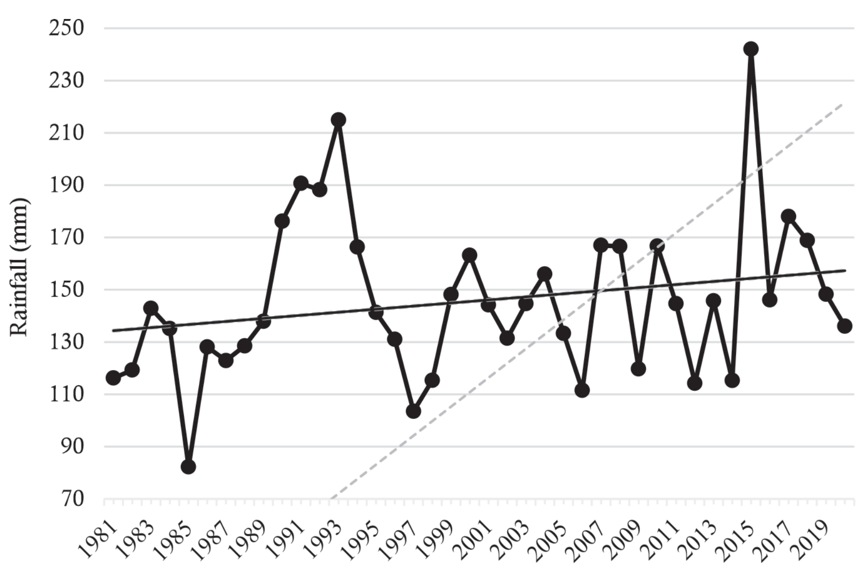

Fig. 4. Variation of rainfall over years at Kohima Station

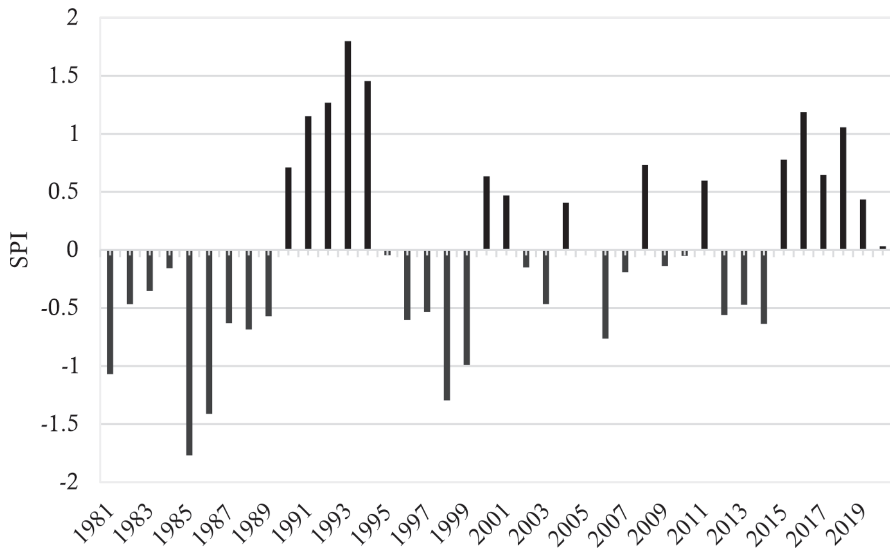

Fig. 5. The change of SPI values over years at Kohima Station

Table 1a. Mann-Kendall Trend of Maximum and Minimum Temperature for different periods

Period	Maximum Temperature	Minimum Temperature
1988-1996*	Increasing	Decreasing
1997-2002	Increasing	No trend
2003-2008	Increasing	Decreasing
2009-2014	Increasing	Decreasing
2015-2020	Decreasing	No trend

*Missing data within this period, hence the period is more than six years.

Table 1b. Mann-Kendall Trend of Rainfall for different periods

Period	Rainfall
1981-1988	Increasing
1989-1996	Decreasing
1997-2004	Increasing
2005-2012	Increasing
2013-2020	No trend

Table 2. SPI values for different years in the Kohima District

SPI value	Dry/Wet conditions	Year of occurrence
1.0 to 1.9	Moderately wet	1991 to 1994, 2016, 2018
-0.99 to 0.99	Near normal	1982 to 1984,1987 to 1990, 1995 to 1997, 1999 to 2015, 2017, 2019, 2020
-1.0 to -1.99	Moderately dry	1981, 1986, 1998
-1.5 to -0.99	Severely dry	1985

positive trend, and the rainfall trend fluctuates (Table 1 a & b).

Variation of SPI

The change of SPI over the years (Figure 5) shows a pattern related to climate change. In 1985, it indicated severely dry weather conditions. From 1991 to 2020, the SPI stayed from -1.5 to -1.99 values. It ranged between moderately dry or wet to near normal weather conditions (Table 2). A helpful indicator for drought analysis is plotting between year and SPI, which provides information about a station's history of droughts.

CONCLUSION

The maximum temperature exhibits a trend toward an increase, whereas the minimum temperature exhibits a trend toward a decrease. Over the years, there has been a decrease in the research area's mean temperature and a mix of both increase and decrease trends of annual rainfall. The research area may experience changes in these parameters due to climate change.

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