https://doi.org/10.48047/AFJBS.6.12.2024.5714-5720

AFJBS African Journal of Biological Sciences
Journal homepage: http://www.afjbs.com

Research Paper Open Access

Detection of Annual Rainfall and Temperature Trend in Kohima Station, Nagaland, India

[1]Ms. Visakhonuo Kuotsu, [2]Dr Pramod Chandra Dihingiaand [3]Dr Khan Chand
[1]Research Scholar, [2]Assistant Professor and [3]Associate Professor
[1&2]Department of Agricultural Engineering & Technology, School of Engineering and Technology, Nagaland University, Distt: Dimapur
[3]Department of Agricultural Engineering, School of Agricultural Sciences, Nagaland University, Medziphema, Distt: Chumukedima
Corresponding author: pramod@nagalanduniversity.ac.in and kcphpfe@gmail.com

Article History
Volume 6, Issue 12, 2024
Received: 30 June 2024
Accepted: 20 July 2024
Doi:
10.48047/AFJBS.6.12.2024.5714-5720

Abstract
Monitoring the precipitation pattern and fluctuations in temperature can assist in predicting future climate conditions, replenishing groundwater, and determining the amount of water available for crops. The objective of this study is to examine the variations in Standardized Precipitation Index (SPI) values over time and identify the annual patterns of rainfall and temperature using the Mann-Kendall test. The Standardized Precipitation Index is employed to evaluate the magnitude of drought and wet conditions throughout time. The results suggest that the maximum temperature increased till 2014, but from 2015 to 2020, it did not show any apparent trend. In contrast, the minimum temperature decreased in three specific time intervals (1988–1996, 2003–2008, and 2009–2014), but there was no apparent trend in the other two periods. The temporal fluctuations of the SPIexhibit an evident trend that is linked to the phenomenon of climate change. In 1985, there were indications of severely dry weather conditions. The SPI value had a range of -1.5 to -1.99 between 1991 and 2020. It varied from moderately dry or wet to near-normal weather conditions.

Key words: Rainfall trend, temperature trend, climate change,Mann-Kendall and SPI

INTRODUCTION

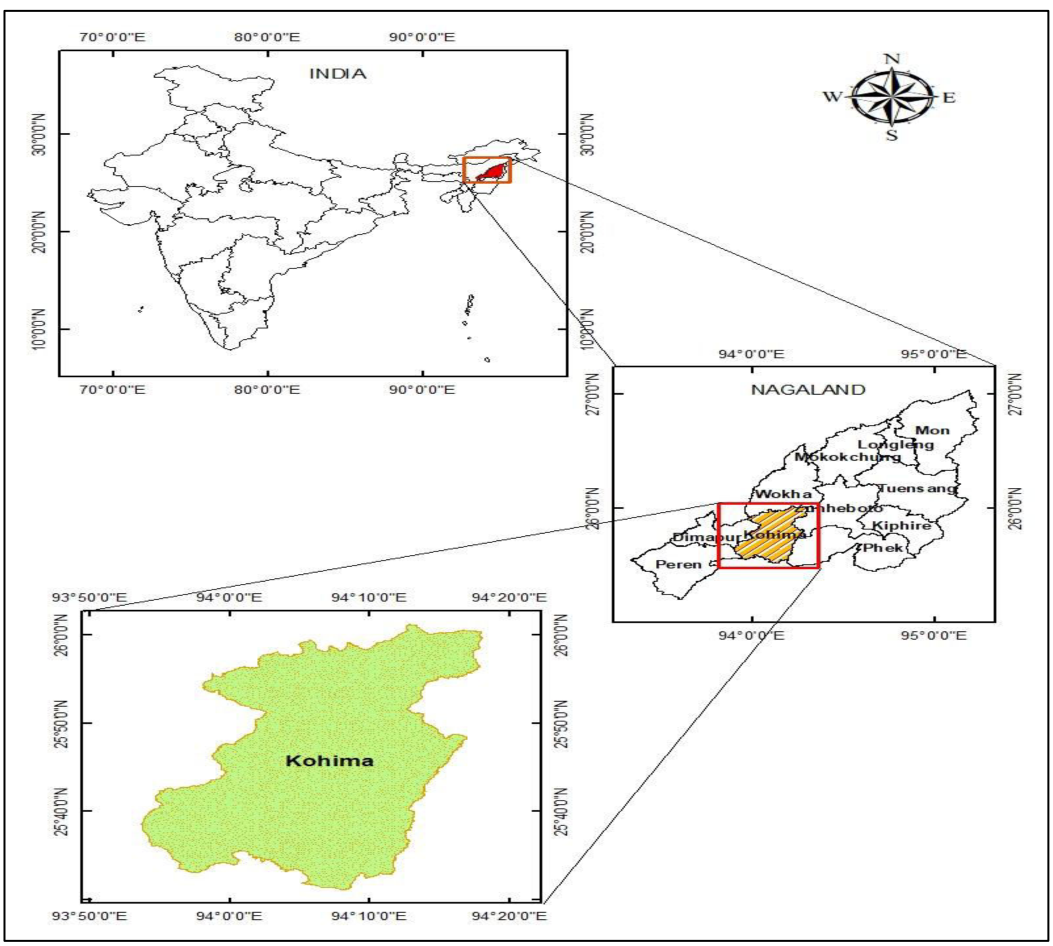
A close link exists between weather and agriculture. Water availability for irrigation and rainfall are two significant factors affecting Indian agriculture. The agriculture production system is still being determined due to the recent variations in rainfall patterns and intensity (Dash et al., 2007). 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 and Kumar, 2012).

Furthermore, climatic variable trend research can aid in creating projected climate scenarios (Pal and 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). Moreover, no such study has been done by the researchers so far in the hilly area of 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. Therefore, it is necessary to detect shifting trends in rainfall and temperature to assess crop water availability, groundwater recharge, and many other aspects.

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 (Fig. 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 of 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 soyabean.

Figure 1: Location of the Study Area



Collection of Meteorological data: The meteorological data for Kohima station was collected from the Soil and Water Conservation Department of the Government of Nagaland. The daily rainfall data from 1981 to 2020 and daily temperaturedata from 1988 to 2020 were used for the trend analysis and evaluationof SPI values.

Trend analysis: Analysis of trends in a time series involves examining the strength of the trend and its statistical relevance. The trend is determined by the relationship between the two variables of temperature, rainfall, and their temporal resolution. Various methods have been used by different researchers for detecting trends. These methods include linear regression analysis, moving averages, time series decomposition, and non-parametric tests. In this study, the trend was derived and tested by the Mann–Kendall test and the slope of the regression line using the least squares method. A linear equation, y = mt + c, defined by c (the intercept) and trend m (the slope), can be fitted by regression. The linear trend value represented by the slope of the simple least-square regression line provided the rate of rise/fall in the variable. The trend of the temperature data's five-year moving average was also analyzed.

Mann-Kendal test: The Mann-Kendall test was used to determine the temperature and rainfall trends over eight years.The test proposed by Mann (1945), and 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 series of rainfall 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 location, 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:

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

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.

Result and discussion

*Variation of temperature and rainfall:*The Kohima Station's annual temperatures show that the maximum temperature trend continually increases while the minimum temperature decreases (Fig. 2). 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:

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

Therefore, the mean temperature decreases by -0.0058°C per year. The five-year moving average shows an increasing trend of mean temperature (Fig. 3). From 1993 to 2002, the five-year average mean temperature fluctuates between 17.5 to 18°C, and there is a fall of average temperature up to 2007 till the mean temperature touches 17°C. However, after 2015, the five-year moving average never fell below 17.5°C. Thus, a slight shifting of temperature is indicated through this study. The variation of rainfall shows an increasing trend during the study period (Fig. 5). There is a fall in annual rainfall in the year 1985, which is higher. The effects of climate change also indicate a rise in rainfall variability over time (IPCC, 2013).

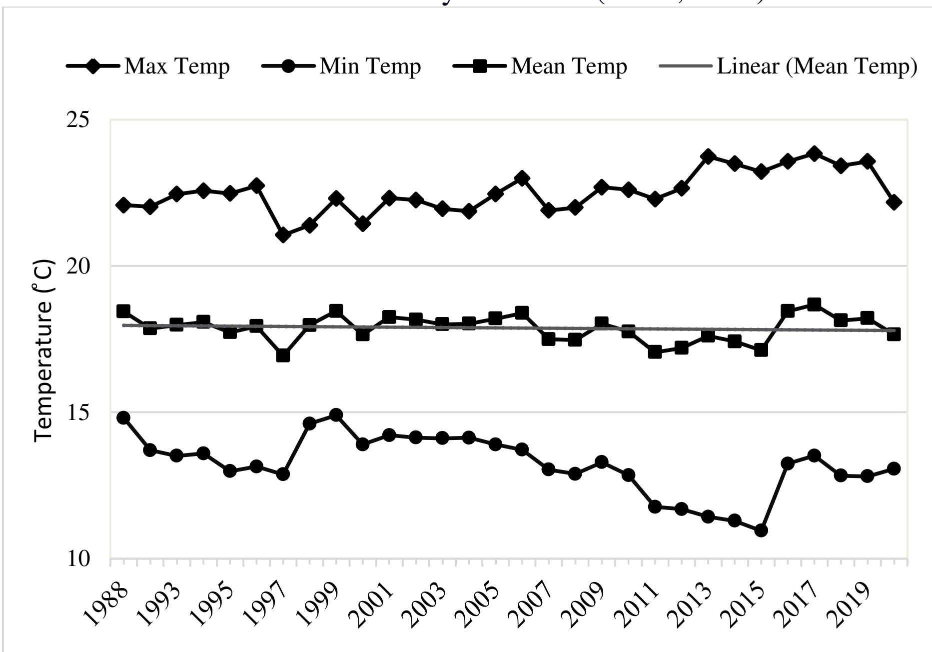


Figure 2: Variation of minimum, mean and maximum temperature over years in Kohima.

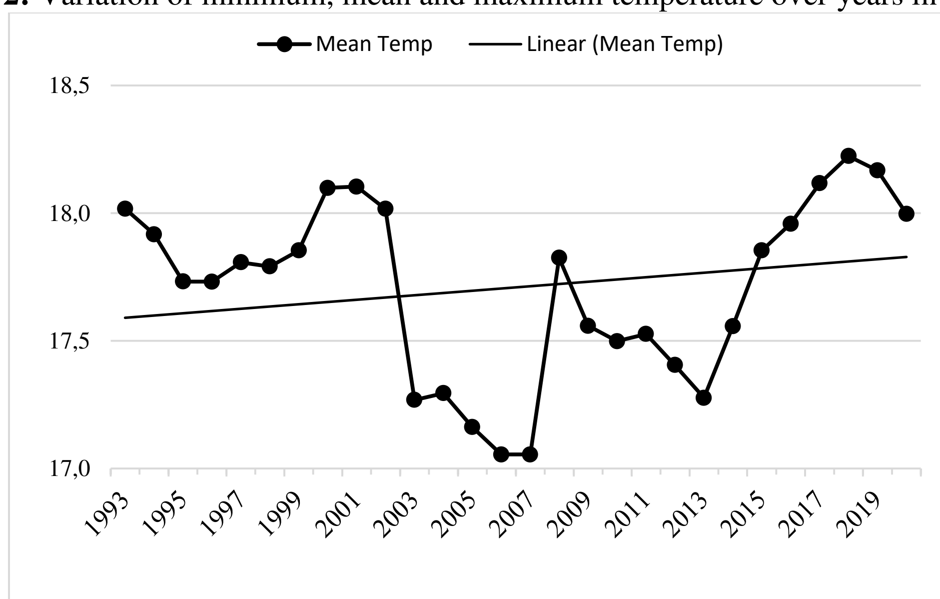


Figure 3: Five-years moving average of mean temperature over years in Kohima

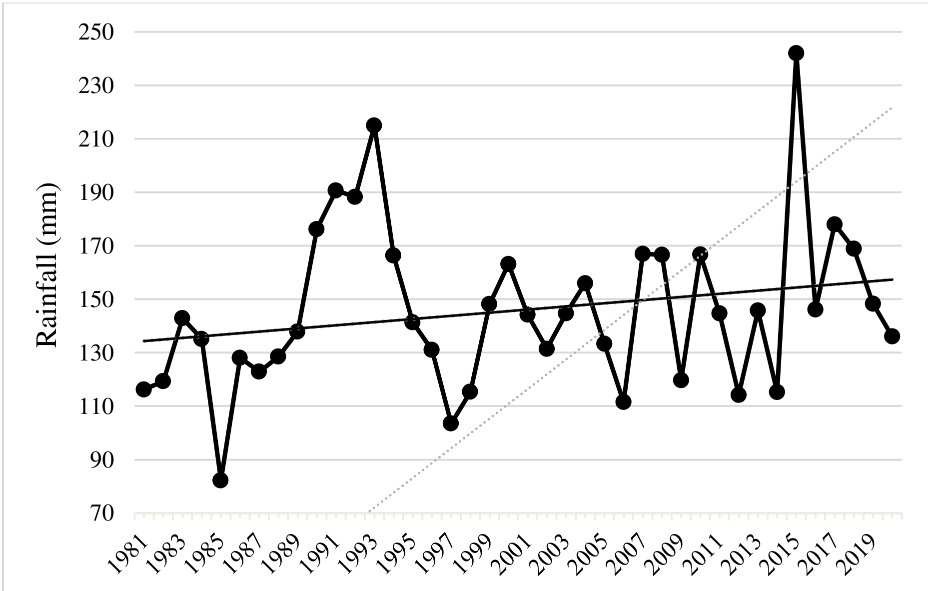


Figure 4: Variation of rainfall over years at Kohima Station.

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 shows an increasing trend up to 2014, after which it shows 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 positive trend, and the rainfall trend fluctuates (Table 1 a & b).

Table 1 a: 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

Variation of SPI: The change of SPI over the years (Fig. 4) 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.

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

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

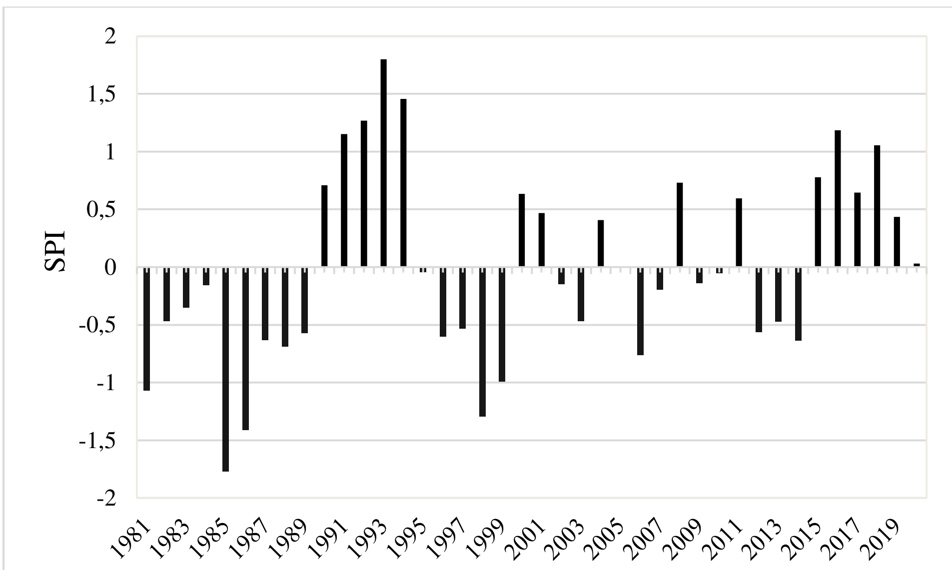


Figure 5: The change of SPI values over years at Kohima Station.

Conclusions

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.

Acknowledgments:

We are greatly thankful to the Soil and Water Conservation Department, Government of Nagaland, for providing the meteorological data for Kohima station, used in this research article and for their effective response and Also would like to thank to the head of the department of SET for providing necessary facilities for conducting research work.

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