International Journal of Bio-resource and Stress Management
https://ojs.pphouse.org/index.php/IJBSM
Crossref
IJBSM February 2026, 16(2): 01-10
Article AR6680
Research Article
Stress Management
DOI: HTTPS://DOI.ORG/10.23910/1.2026.6680

Temperature Trend Analysis for Climate Change Assessment in the South-Eastern Plateau of Jharkhand

Ravi Ranjan Kumar[1], Moumita Baishya[2], Ankita Kumari[3], Amit Kumar[4] and Avinash Kumar[5]

[1]Dept. of Basic Sciences, [4]Dept. of Vegetable Science, [5]Dept. of Social Sciences, Horticultural College, Khuntpani, Chaibasa, Jharkahnad (835 204), India
[2]College of Basic Sciences & Humanities, Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar (848 125), India
[3]Dept. of Agronomy, Bihar Agricultural College, Sabour, Bhagalpur, Bihar (813 210), India

Open Access

Corresponding tan2ravi@gmail.com

0000-0001-6174-3295

ABSTRACT

The present study was carried out during January, 1981 to December, 2024 in the districts (Singhbhum, East Singhbhum, and West Singhbhum) of the South-Eastern Plateau Zone of Jharkhand. In this study, the trends of air temperature were detected using the Mann–Kendall test with Sen's slope estimator for annual and seasonal temperatures. The climatic parameters provided an ongoing need for thorough research to mitigate the unintended, severe consequences of climate change. According to past research, the trend analysis method was regarded as one of the most popular and successful approaches. Therefore, in this article, the seasonal, annual, and monthly temperatures of the Southeastern Plateau of Jharkhand were fetched and analyzed for the period interval of 44 years (1981 to 2024) by using nonparametric tests. The results obtained consisted of trend values along with trend slope and polygon graphics (arithmetic). According to the results, it was observed that the minimum temperature exhibited a significant upward trend in the spring, summer, and autumn seasons except for the winter season, while the maximum temperature displayed a downward trend in most of the seasons. The greater variability of the temperatures observed in winter seasons throughout the years.

KEYWORDS: Temperature trend, IPTA, Mann Kendall, Sen's Slope

Citation* (VANCOUVER)*: Kumar et al., Temperature Trend Analysis for Climate Change Assessment in the South-Eastern Plateau of Jharkhand. *International Journal of Bio-resource and Stress Management,* 2026; 16(2), 01-10. HTTPS://DOI.ORG/10.23910/1.2026.6680.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The authors have declared that no conflict of interest exists.

RECEIVED on 10th September 2025 RECEIVED in revised form on 16th January 2026 ACCEPTED in final form on 04th February 2026 PUBLISHED on 12th February 2026

1. INTRODUCTION

The climate is an extremely important part of the Earth's ecosystem. There are a lot of factors involved in making up weather and climate, such as the temperature, the amount of precipitation, the pressure in the atmosphere, and the amount of humidity. Changes in climatic variables over long periods of time are an essential part of research that tries to find evidence of climate change. The impact of climate change is more in developing countries like India in view of its huge population, rise in standard of living of the population, industrialization, excessive pressure on natural resources, etc. According to Indian Metrological Department (IMD) statistics (Rathore et al., 2013), between 1951 and 2010, the annual mean surface temperature in India decreased in northern states and remained constant in northeastern states, while increasing in all other states. In the Eastern Plateau and Hilly Region of India, the majority of agricultural output comes from rainfed areas and is largely controlled by the timely availability of water. Therefore, regional differences in temperature and precipitation have been found to be significantly more pronounced, and there may be significant geographical and temporal variance between climatically distinct locations (Yue and Hashino, 2003). As a result, it is asserted that observations of historical climate at the global level may not be very helpful for planning at the local or regional level. Therefore, investigation of climate change at the regional level is very important to identifying the impacts of climate change on ecosystems, and a proper assessment of variability and changes in pattern and existence of trends in weather parameters over different spatial horizons would be helpful to the planners in the disaster adaptation and mitigation strategies. In the recent past year, many researchers have focused on analyzing temperature trends over a geographical region (Chakma and Biswas, 2022; Datta et al., 2022; Elzopy et al., 2020; Mandal et al., 2019; Pingale et al., 2014). Various statistical methods have been used in research to identify trends and changes in climatic variables across time scales. Nonparametric (Mann-Kendall test) and parametric (linear regression analysis) methods have been used to identify yearly and seasonal trends (Sarkar and Kumar, 2023; Norbu and Basnet, 2022; Praveen et al., 2020; Chandole et al., 2019; Panda and Sahu, 2019; Bhuyan et al., 2018; Radhakrishnan et al., 2017; Feng et al., 2016; Nema et al., 2016; Bibi et al., 2014; Jeganathan and Andimuthu, 2013; Tramblay et al., 2013; Saboohi et al., 2012; Yavuz and Erdogan, 2012). However, nonparametric tests are most widely used for trend analysis of climatic variables. The non-parametric tests have many advantages, such as the requirement of few assumptions, handling of missing data, and independence of the data distribution.

Keeping in view this discussion, there is a need for an objective methodology for trend analysis of temperature. The main aim of the present research work was to identify the annual and seasonal maximum and minimum temperature trends at different spatial and temporal scales for the South-Eastern Plateau Zone of Jharkhand. In this study, the trends of air temperature were detected using the Mann-Kendall test with Sen's slope estimator for annual and seasonal temperatures. A new method, Innovative Polygon Trend Analysis (IPTA), developed by Sen in 2019, has been used to detect abrupt changes and directional changes in the time series data. It is more effective than conventional non-parametric tests in trend analysis, and it has been used extensively to examine weather patterns across the world (Achite et al., 2021).

2. MATERIALS AND METHODS

2.1. Study area

The present study was carried out during January, 1981–December, 2024 in the districts of the South-Eastern Plateau Zone of Jharkhand (Figures 1 and 2). The state was bounded by 21° 95' to 25° 45'N latitude and 83° 35' to 87° 95'E longitude and has a total geographical area 79,714 km². It was located in the country's northeast and has borders with Bihar to the north, West Bengal to the east, Odisha to the south, Chhattisgarh to the west, and Uttar Pradesh to the northwest. Jharkhand was divided into three agro climatic zones: The Central and Northeastern Plateau subzone, the Western Plateau subzone, and the Southeastern Plateau subzone. In this investigation, the South Eastern Plateau subzone has been selected for climate change assessment. This zone included the districts of Singhbhum, East Singhbhum, and West Singhbhum, and the climate ranges from sub-humid to humid, with increased rainfall.

2.2. Data and methods

The Weather observations were obtained from two climatic variables: Maximum Temperature (T_{max}) and Minimum Temperature (T_{min}), from NASA prediction of worldwide energy resources (Anonymous, 2025). Gridded data sets (0.5° latitude×0.5° longitude spatial resolution) of monthly temperature (°C) from the period January, 1981 to December, 2024 have been recorded. Furthermore, the time series were divided into five data sets: annual and seasonal, as defined by the India Meteorological Department (IMD) guidelines: winter (December-February), spring (March-May), summer (June-August), and autumn (September-November).

2.3. Trend analysis

2.3.1. Mann-Kendall (MK) test

Mann Kendall test has been used for the identifying trends in the spatio-temporal data. The advantage of non-

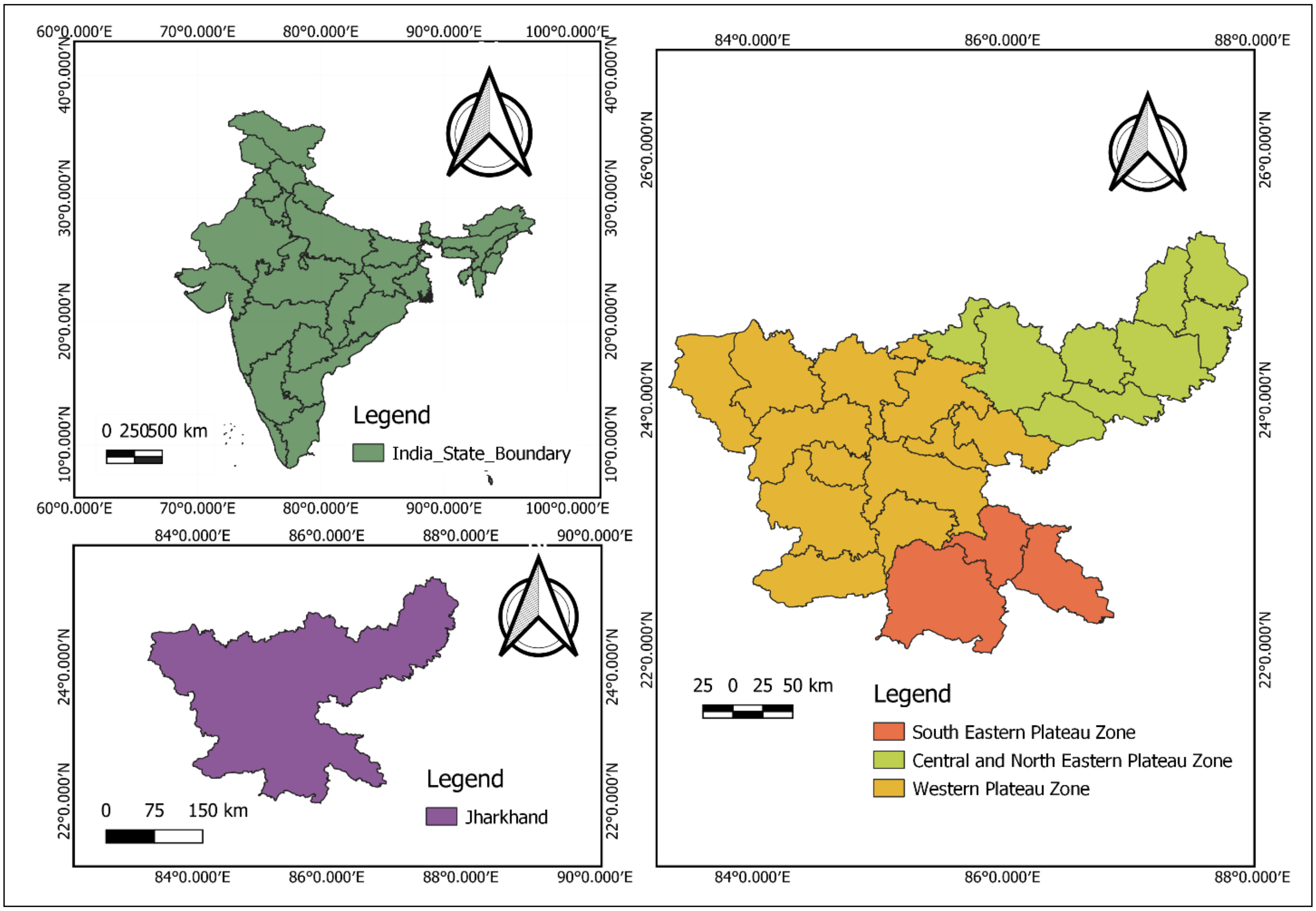

Figure 1: Map of agro climatic zones of Jharkhand, India

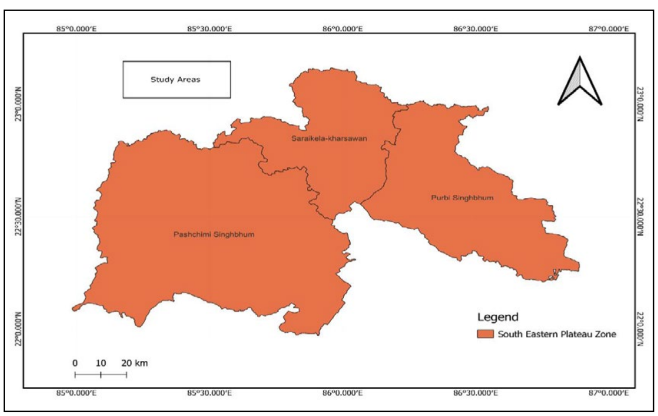

Figure 2: Geographical Map of the Study areas (South Eastern Plateau)

parametric test over parametric test, it did not require the data to be normally distributed. The MK test statistics (S) could be computed as follows.

Null hypothesis (H_0): A trend is present.

Alternative hypothesis (H_1): A trend is not present

The Mann-Kendall test statistic (S):

$$S=\sum_{i=1}^{n-1}\sum_{j=i+1}^{n}\mathrm{sgn}(X_j-X_i) \quad (1)$$

where n was the number of the data points, X_i was the observed value at time i (i =1,2,.., n) and X_j is the observed value at time j (j=i+1,i+2, ..., n). The value of $\mathrm{sgn}(X_j-X_i)$ was computed using the $\mathrm{sgn}(X_j-X_i)$ as follow:

$$\mathrm{sgn}(X_j-X_i)=\begin{cases}+1, & (X_j-X_i)>0\\ 0, & (X_j-X_i)=0\\ -1, & (X_j-X_i)<0\end{cases} \quad (2)$$

The test was carried out using a normal approximation (Z statistics) for large samples (n>10), with the mean and variance as follows:

$$E(S)=0, \quad (3)$$

$$Var(S)=1/18[n(n-1)(2n+5)-\sum_{p=1}^{q}t_p(t_p-1)(2t_p+5)] \quad (4)$$

where q was the number of tied (zero difference between compared values) groups and t_p was the number of data values in the p^{th} group. Test statistic Z as follows:

$$Z=\begin{cases}\frac{s-1}{\sqrt{var(s)}} & \text{if } S>0\\ 0 & \text{if } S=0\\ \frac{s+1}{\sqrt{var(s)}} & \text{if } S<0\end{cases} \quad (5)$$

A statistically significant trend is evaluated using the Z value which positive value of Z indicated an increasing trend and its negative value a decreasing trend. Null hypothesis (H_0) was tested at p=0.05 level of significance ($Z_{0.05}$=1.96).

Sen's slope estimator

Sen's nonparametric technique has been used to determine the true slope of an existing trend (as change year^{-1}). The Sen's method (Sen, 1968) could be used in cases where the trend could be assumed to be linear.

Q=Median (X_j-X_i/j-i) ....(6)

where X_j was the observed value at time j and X_i is the observed value at time i. Q was a magnitude of trend estimate. Sen's slope indicated an increasing trend for positive value and a decreasing trend for negative value in the time series data.

2.3.3. Innovative trend polygon analysis (ITPA)

The innovative polygon trend analysis (IPTA) was a relatively new method for detecting trends in time series data. developed by Sen in (2019). A time series was divided into segments for the IPTA method, and a polygonal line was then fitted to each segment. Instead of the non-parametric test used in the conventional trend analysis methodology, the least-squares method was used in the IPTA approach to fit polygonal lines. The presence or absence of trends was then determined by the approach by performing a significance test on each of the segments.

$E(s)=2/n\,[E(\bar{X}_2)-E(\bar{X}_1)]$ ....(7)

If the values of $E(\bar{X}_2)=E(\bar{X}_1)$, therefore E(s)=0; and this implied there was no trend. Otherwise, the difference between $E(\bar{X}_2)$ and $E(\bar{X}_1)$ gave the variance of the slope:

$\sigma s^2=E(s^2)-E^2(s)=4/n^2\,[E(\bar{X}_2)-2E(\bar{X}_2\bar{X}_1)]+E(\bar{X}_1^2)$ ....(8)

As $E(\bar{X}_2^2)=E(\bar{X}_1^2)$, the above equation becomes:

$\sigma_s^{\,2}=8/n^2[E(\bar{X}_2)-E(\bar{X}_2\bar{X}_1)]$

Therefore, the relationship was obtained with the equations;

If, $\bar{X}_2=\sigma\bar{X}_1=\sigma/\sqrt{n}$;

$\sigma^2_s=8/n^2\ \sigma^2/n\ (1-\rho\bar{X}_1\ \bar{X}_2)$

$\sigma_s=(2\sqrt{2}/n\sqrt{n})\ \sigma\sqrt{(1-\rho\bar{X}_1\bar{X}_2)}$

Where,

$\rho\bar{X}_1\bar{X}_2=\{E(\bar{X}_1\bar{X}_2)-E(\bar{X}_1)E(\bar{X}_2)\}/(\sigma\bar{X}_1\ \sigma\bar{X}_2)$

Finally, the confidence limit (CL) trend slope was calculated as

CL_((1-α))=0±S_cri*σ_s ....(9)

Where, in stochastic processes $\rho\bar{X}_1\bar{X}_2$ was the correlation coefficient between the two mean values. CL represented the upper and lower confidence levels at the α level of significance, whereas σ_s denoted the standard deviation.

The null hypothesis (Ho): There was no pattern in the time-series data.

The alternate hypothesis (H_1): A trend in the time-series data has been noticed.

Therefore, the Ho and H_1 were examined at α=5% with Z=±1.96 in a two-tailed condition. If ±s>±CL(1-α), Ho was rejected and H_1 accepted. The positive and negative values of S implied that the time-series data was rising or dropping, respectively.

3. RESULTS AND DISCUSSION

3.1. Serial correlation

The trend detection process might be impacted by the existence of any positive or negative correlations. Lag-1 serial correlation was therefore utilized before doing the MK test to determine whether any trends already existed in the dataset. All of the series were determined to be non-auto correlated based on the autocorrelation test results. The MK test was then applied to the non-auto correlated data series at the p=0.05 significance level over 44 years.

3.2. Temperature variability

The descriptive statistics of annual and seasonal (spring, winter, summer, and autumn) maximum temperature (T_{max}) and minimum temperature (T_{min}) have been computed, such as the mean, standard deviation (SD), and coefficient of variation (CV), and were presented in Tables 1 and 2.

West Singhbhum District: The annual mean T_{max} and T_{min} for the period 1981–2024 are 34.91°C and 16.22°C with standard deviations of 0.64°C and 0.46°C, respectively. The lowest annual mean T_{min} was observed in the year 2012 (15.14°C), and the highest annual mean T_{max} was observed in the year 2010 (36°C). The T_{max} variability patterns over 1981–2024 were greater in the winter season (4.09%) and lesser in the annual (1.83%) and autumn seasons (2.30%). The T_{min} variability patterns over 1981–2024 were greater in the winter season (13.41%) and lesser in the summer season (1.415%). Overall, there has been high variation occurring in the winter season as compared to other seasons for both the T_{max} and T_{min}.

3.2.1. Singhbhum and east singhbhum districts

The annual mean T_{max} and T_{min} for the period 1981–2024 were 35.02 °C and 16.34 °C with standard deviations of 0.73 °C and 0.47 °C, respectively. The lowest annual mean T_{min} was observed in the year 1984 (15.38 °C), and the highest annual mean T_{max} was observed in the year 1989 (36.60°C). The T_{max} variability patterns over 1981–2024 were greater in the winter season (4.50%) and lesser in annual (2.07%) and autumn seasons (2.22%). The T_{min} variability patterns over 1981–2024 were greater in the winter season (13.55%) and lesser in the summer season (1.62%). Overall, there has been high variation occurred in winter seasons as compared to

Table 1: Descriptive statistical analysis of temperatures for West Singhbhum district

Seasons	West Singhbhum District					
	Maximum temperature			Minimum temperature		
	Mean (°C)	Standard deviation	CV (%)	Mean (°C)	Standard deviation	CV (%)
Spring	42.831	1.090	2.545	18.590	0.957	5.146
Winter	31.152	1.276	4.095	7.512	1.008	13.413
Summer	35.539	1.383	3.892	23.053	0.326	1.415
Autumn	30.099	0.693	2.301	15.721	0.909	5.783
Annual	34.910	0.640	1.833	16.220	0.460	2.836

Table 2: Descriptive statistical analysis of temperature for Singhbum and East Singhbhum districts

Seasons	Singhbum and East Singhbhum districts					
	Maximum temperature			Minimum temperature		
	Mean (°C)	Standard deviation	CV (%)	Mean (°C)	Standard deviation	CV (%)
Spring	43.061	1.153	2.679	18.582	1.039	5.593
Winter	30.459	1.373	4.507	6.974	0.945	13.553
Summer	36.554	1.550	4.240	23.868	0.387	1.622
Autumn	30.726	0.684	2.226	15.920	1.016	6.381
Annual	35.200	0.730	2.074	16.340	0.470	2.876

other seasons for both the T_{max} and T_{min}. It was noteworthy that the districts of Singhbum and E. Singhbum faced slightly higher temperatures compared to W. Singhbum, which might be due to their presence of industry and deforestation.

3.3. Temperature trend

3.3.1. West Singhbhum District

The analysis of temperature trends in West Singhbhum district using both the Mann-Kendall test and Sen's slope revealed significant findings (Table 3). The Mann-Kendall test indicated notable trends in both the T_{max} and T_{min}. Specifically, the T_{min} exhibited a significant upward trend in spring, summer, and autumn seasons except for the winter season, while the T_{max} displayed a significant downward trend in spring, winter, and annual seasons. It could also be seen from the trend plots in T_{max} and T_{min} of West Singhbhum district (Figures 3 and 4). Additionally, the Sen's slope analysis further supported these findings by revealing a decreasing trend in T_{max} and an increasing trend in T_{min}. The Sen's slope value for T_{min} ranges from -0.016 in winter to 0.031 in autumn. The negative slope values in the winter season indicated a decreasing trend over the years, while the positive values in the spring, summer, and autumn seasons indicated an increasing trend. Similarly, the Sen's slope value for T_{max} ranges from -0.016 in winter to -0.031 in spring.

Table 3: Trend results of temperatures for West Singhbhum district

Seasons	West Singhbhum district			
	Maximum temperature		Minimum temperature	
	MK test (Z value)	Sen's slope estimate	MK test (Z value)	Sen's slope estimate
Spring	-2.428^{**}	-0.031	1.952^{*}	0.023
Winter	-2.418^{**}	-0.016	-2.064^{**}	-0.016
Summer	-0.657^{NS}	-0.013	2.165^{**}	0.009
Autumn	-1.042^{NS}	-0.009	2.934^{**}	0.031
Annual	-2.802^{*}	-0.022	1.740^{NS}	0.010

This suggested that the winters were getting slightly cooler for both T_{max} and T_{min}, while the summers were becoming slightly warmer. Overall, the results suggested that the T_{min} was increasing, which could have implications for the industry and deforestation.

3.3.2. Singhbhum and West Singhbhum districts

The Mann-Kendall test results for the T_{min} observed a significant upward trend in the seasons of summer, autumn, and annual, while a downward trend was observed in the winter season. In the case of T_{max}, it showed a significant downward trend in the spring, winter, and annual seasons

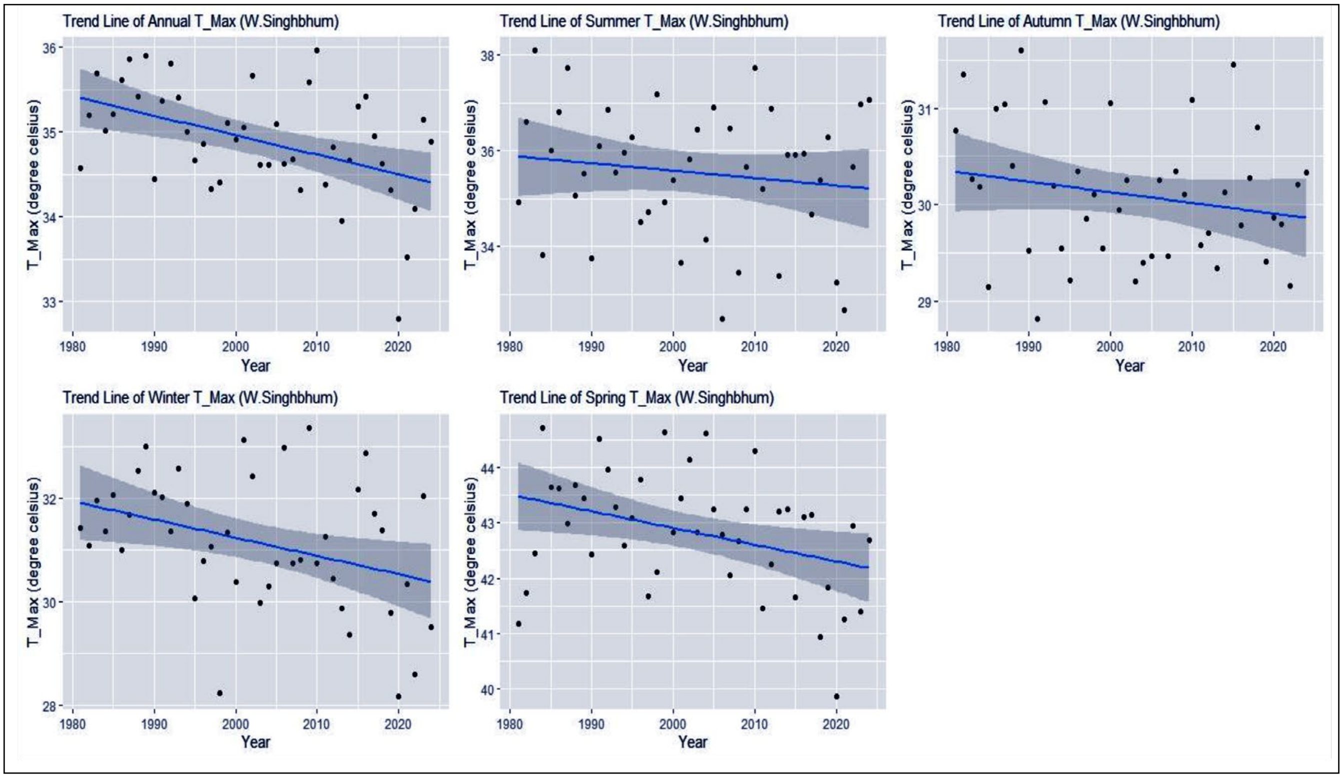

Figure 3: Annual and seasonal trend plots in the maximum temperature for West Singhbhum district

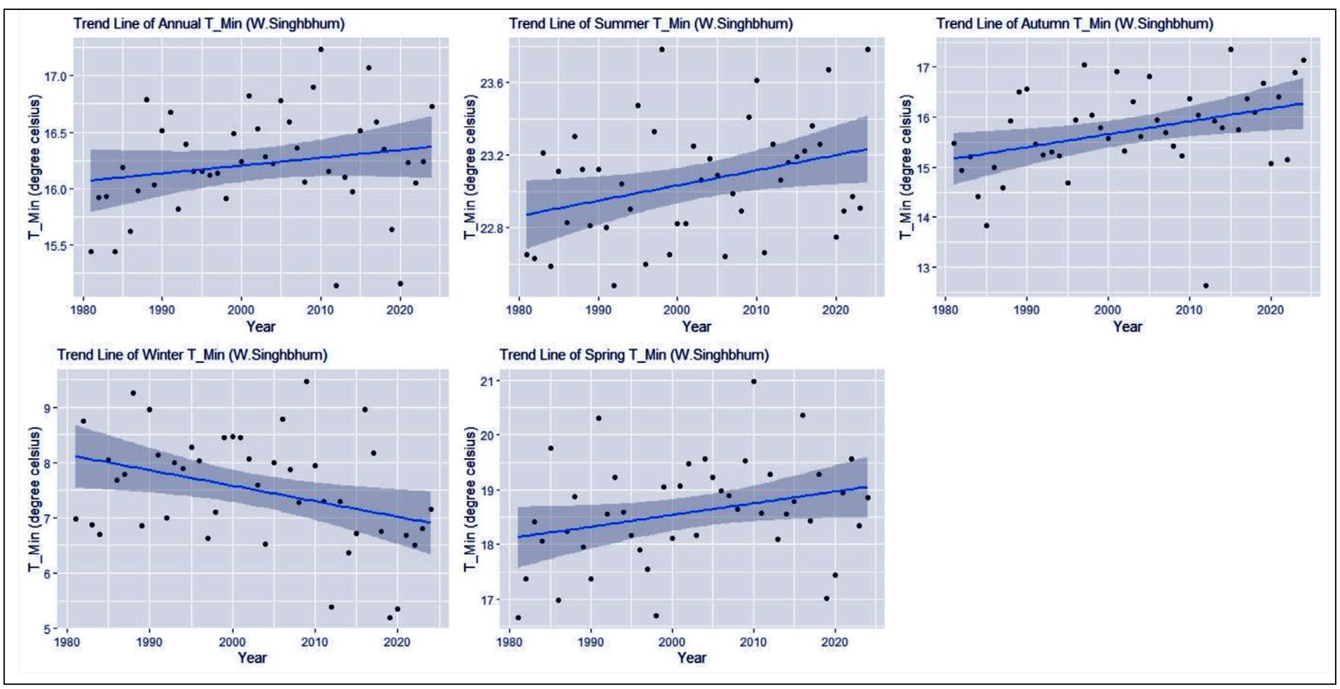

Figure 4: Annual and seasonal trend plots in the minimum temperature for West Singhbhum district

(Table 4). Trend plots also justified the increasing trend in T_{min} and decreasing trend in T_{max} for the selected areas (Figures 5 and 6). Additionally, the Sen's slope analysis further supported these findings by revealing a decreasing trend in T_{max} and an increasing trend in T_{min}. The Sen's slope value for T_{min} ranges from -0.028 in winter to 0.041 in autumn. The negative slope values in the winter season indicated a decreasing trend over the years, while the positive values in the summer, autumn, and annual seasons indicated an increasing trend. Similarly, the Sen's slope value for T_{max}

ranges from -0.027 in annual to -0.052 in winter. This suggested that the spring and winter seasons were getting slightly cooler for the T_{max}. Overall, these results suggested that there was a noticeable change in temperature patterns in both the Singhbhum and E. Singhbhum districts. The increases trend of minimum temperature was also observed in Bihar State (Sarkar and Kumar, 2023)

3.4. Innovative polygon trend analysis

The IPTA technique was employed to analyze the average monthly temperature data, including maximum and minimum temperatures, over a period of 1981–2024 in the South-Eastern Plateau. This technique allowed for the projection and examination of the dataset, offering valuable insights into the climate characteristics during the specified timeframe. The resulting IPTA graphs, presented in figures. 7 to 10, represented the respective climate parameters while providing essential statistical measures such as arithmetic mean results. By applying the IPTA method, the trends in monthly mean temperature fluctuations were examined, providing insights into the long-term changes in temperature at these locations. The IPTA method involved calculating distances and slopes between consecutive temperature points. This information aids in visualizing the trends through the construction of polygons that encompassed the temperature data points. Additionally, the method allowed for the identification of areas where temperature trends were increasing or decreasing.

Table 4: Trend results of temperatures for Singhbum and East Singhbhum districts

Seasons	Singhbhum and West Singhbhum Districts			
	Maximum Temperature		Minimum Temperature	
	MK test (Z value)	Sen's slope estimate	MK test (Z value)	Sen's slope estimate
Spring	-2.428**	-0.036	1.629^{NS}	0.021
Winter	-2.903**	-0.052	-2.529**	-0.028
Summer	-0.536^{NS}	-0.012	2.084**	0.010
Autumn	-1.042^{NS}	-0.009	3.257**	0.041

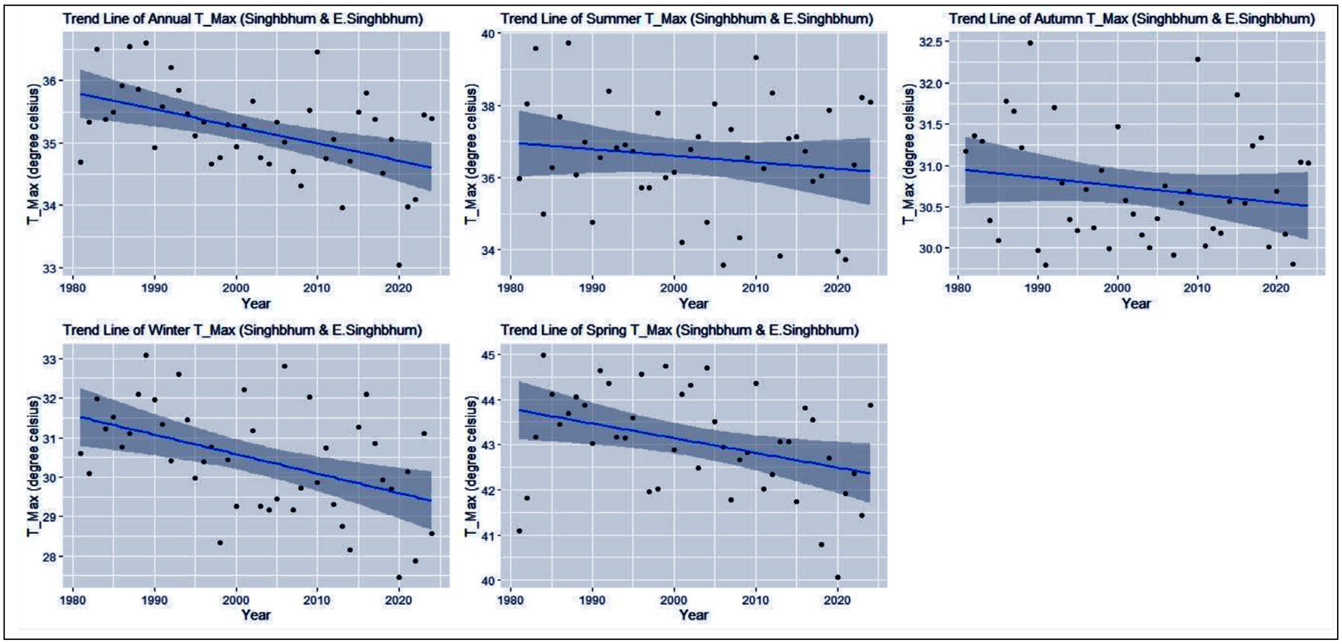

Figure 5: Annual and seasonal trend plots in the maximum temperature for Singhbhum and East Singhbhum districts

When the IPTA graph of the West Singhbhum district was examined in detail on a monthly basis, it was seen that the months without a trend were observed in February, August, September, and October, while a significant decreasing trend was observed in January, March, April, June, July, November, and December for T_{max}. Similarly, the IPTA graph of the T_{min} was examined, and it was seen that the months with a decreasing trend were observed in January, December, and February, while an increasing trend was observed in April, September, and October.

In the case of the Singhbhum and East Singhbhum districts, based on the IPTA graph for T_{max} a decreasing trend was observed in the months of January, February, March, April, June, July, November, and December, however, August, September, and October showed no distinct pattern. Similarly, the IPTA graph for the T_{min} showed that a decreasing trend was observed in the months of January, February, and December, while an increasing trend was observed in the months of April, September, October, and November.

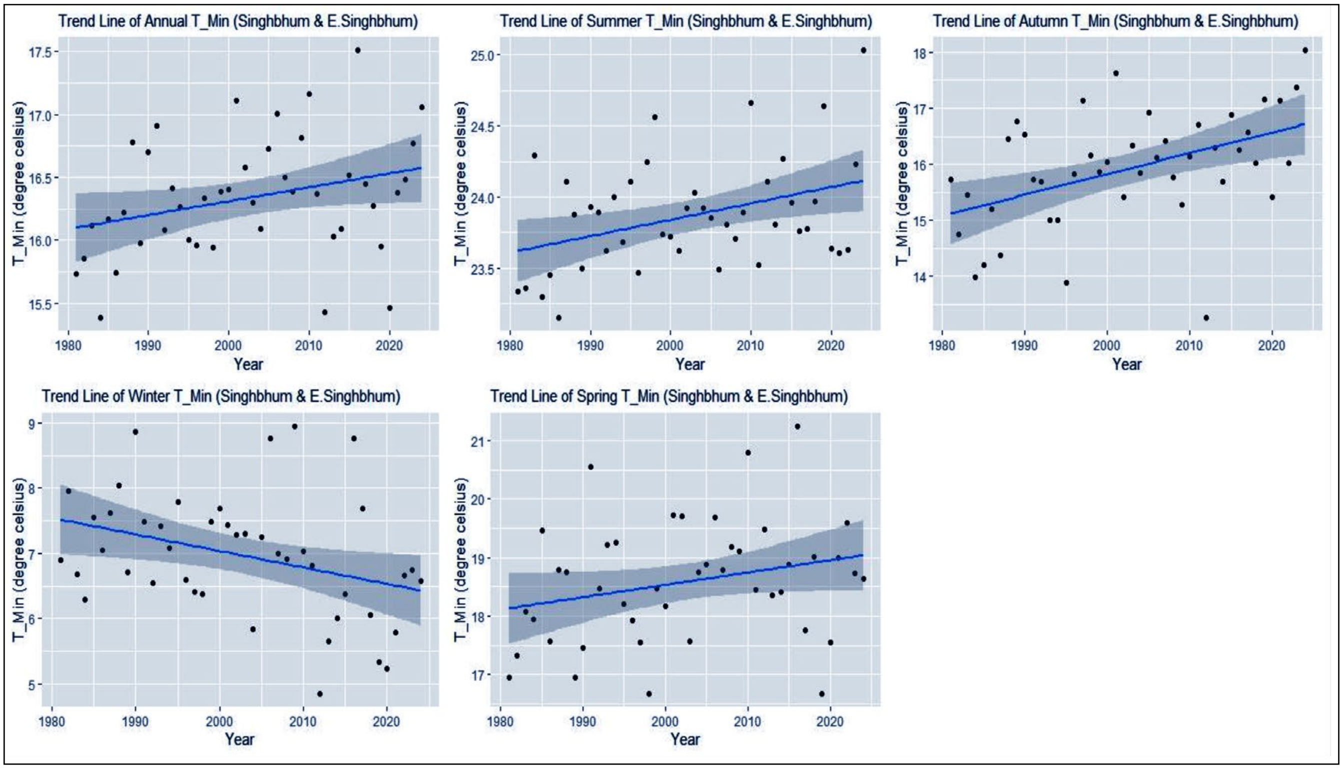

Figure 6: Annual and seasonal trend plots in the minimum temperature for Singhbhum & East Singhbhum districts

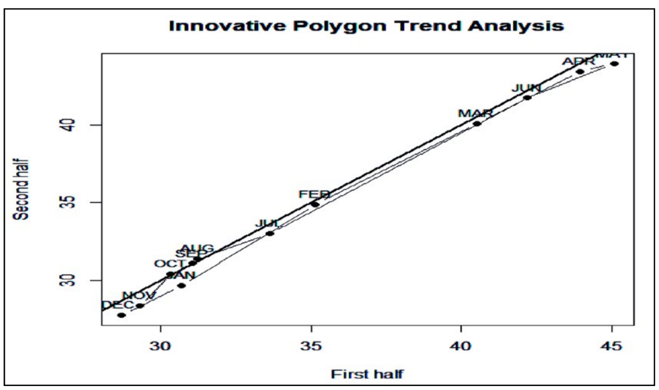

Figure 7: Innovative polygon trend analysis of T_{min} for West Singhbhum district

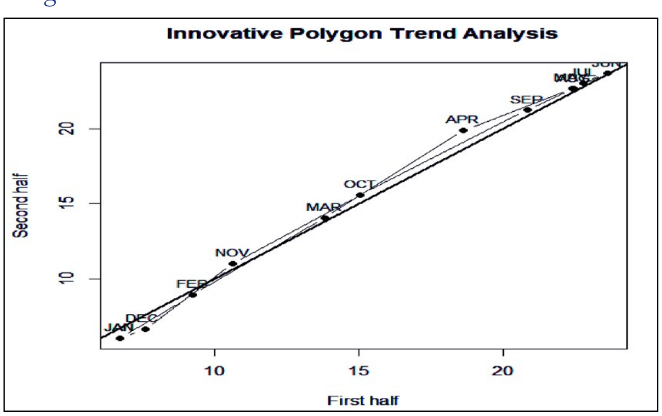

Figure 8: Innovative polygon trend analysis of T_{min} for West Singhbhum

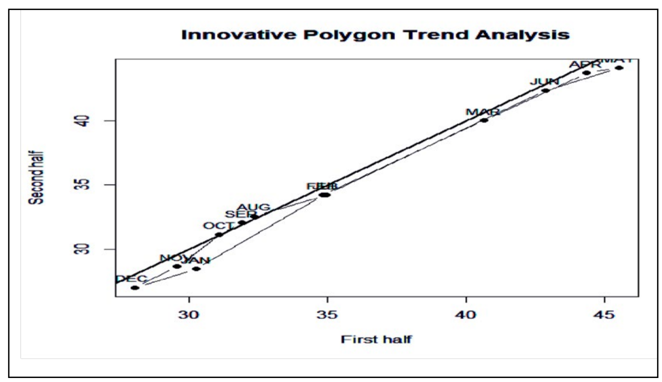

Figure 9: Innovative polygon trend analysis of T_{max} for Singhbhum and E. Singhbhum districts

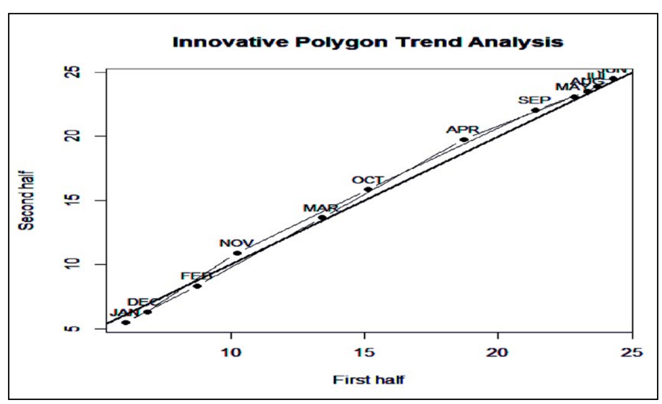

Figure 10: Innovative polygon trend analysis of T_{min} for Singhbhum and E. Singhbhum districts

4. CONCLUSION

A new technique, IPTA, was used to analyze the trend graphically in the monthly temperature. The results revealed that the West Singhbhum showed the upward trends in spring, summer, and autumn seasons except for the winter season for the T_{min}, while the T_{max} observed significant downward trends in spring, winter, and annual seasons. In the case of the Singhbhum and West Singhbhum, the test results of the T_{min} observed upward trend in the seasons of summer, autumn, and annual, while a downward trend was observed in the winter season.

5. ACKNOWLEDGEMENT

We are grateful to the Horticulture College, Khuntpani, Chaibasa, Birsa Agricultural University, Ranchi for all sort of assistance provided during this study.

6. REFERENCES

Achite, M., Ceribasi, G., Ceyhunlu, A.I, Wałega, A., Caloiero, T., 2021. The innovative polygon trend analysis (IPTA) as a simple qualitative method to detect changes in environment: example detecting trends of the total monthly precipitation in semiarid area. Sustainability 13(22), 12674. https://doi.org/10.3390/su132212674.

Anonymous, 2025. NASA prediction of worldwide energy resources. (https://power.larc.nasa.gov/data-access viewer/). Accessed on 29th August, 2025.

Bhuyan, M.D.I., Islam, M.D., Bhuiyan, M.E.K., 2018. A trend analysis of temperature and rainfall to predict climate change for North-western region of Bangladesh. American Journal of Climate Change 7, 115–134.

Bibi, U.M., Kaduk, J., Balzter, H., 2014. Spatial-temporal variation and prediction of rainfall in Northeastern Nigeria. Climate 2(3), 206–222. https://doi. org/10.3390/cli2030206.

Chakma, N., Biswas, S., 2022. Long period trend analysis of precipitation and temperature of West Sikkim, India. Mausam 73(2), 413–422. https://doi.org/10.54302/mausam.v73i2.5484.

Chandole, V., Joshi, G.S., Rana, S.C., 2019. Spatio-temporal trend detection of hydro-meteorological parameters for climate change assessment in Lower Tapi river basin of Gujarat state, India. Journal of Atmospheric and Solar–Terrestrial Physics 195, 105–130. DOI: https://doi.org/10.1016/j.jastp.2019.105130.

Datta, D., Banerjee, S., Kar, G., Ghosh, S., Saha, S., 2022. Spatio-temporal dynamics of temperature and rainfall across jute growing districts of India. Mausam 73(2), 373–388. https://doi.org/10.54302/mausam.v73i2.569.

Elzopy, K.A., Ashish, K., Chaturvedi, K., Madhava, C., Girish, G., Naveena, K., Surendran, U., 2020. Trend analysis of long-term rainfall and temperature data for Ethiopia. South African Geographical Journal 103(3), 381–394. https://dx.doi.org/10.1080/03736245.2020.1835699.

Feng, G., Cobb, S., Abdo, Z., Fisher, D.K., Ouyang, Y., Adeli, A., Jenkins, J., 2016. Trend analysis and forecast of precipitation, reference evapotranspiration, and rainfall deficit in the Blackland Prairie of Eastern Mississippi. Journal of Applied Meteorology and Climatology 55, 1425–1439. https://doi. org/10.1175/JAMC-D-15-0265.1.

Jeganathan, A., Andimuthu, R., 2013. Temperature trends of Chennai city, India. Theoretical and Applied Climatology 111, 417–425. DOI: http://dx.doi.org/10.1007/s00704-012-0646-6.

Mandal, U.K., Nayak, D.B., Mullick, S., Samui, A., Jana, A.K., Mahanta, K.K., Raut, S., Roy, S., Burman, D., 2019. Trend analysis of weather parameters over Indian Sundarbans. Journal of Agrometeorology 21(3), 307–315. http://dx.doi.org/10.54386/jam.v21i3.253.

Nema, S., Awasthi, M., Nema, R.K., 2016. Trend analysis of annual and seasonal rainfall in Tawa command area. International Journal of Environment, Agriculture and Biotechnology 1(4), 952–957. https://doi.org/10.22161/ijeab/1.4.46.

Norbu, S., Basnet, J.B., 2022. Seasonal rainfall trend and annual rainfall variability analysis for selected meteorological stations in Bhutan. Social Science Research Network (SSRN). Available at SSRN: https://ssrn.com/abstract=4027295 or http://dx.doi.org/10.2139/ssrn.4027295.

Panda, A., Sahu, N., 2019. Trend analysis of seasonal rainfall and temperature pattern in Kalahandi, Bolangir and Koraput districts of Odisha, India. Atmospheric Science Letters 20(10), e932. https://doi. org/10.1002/asl.932.

Pingale, S.M., Khare, D., Jat, M.K., Adamowski, J., 2014. Spatial and temporal trends of mean and extreme rainfall and temperature for the 33 urban centers of the arid and semi-arid state of Rajasthan, India. Atmospheric Research 138, 73–90. https://doi.org/10.1016/j.atmosres.2013.10.024.

Pingale, S.M., Khare, D., Jat, M.K., Adamowski, J., 2014. Spatial and temporal trends of mean and extreme rainfall and temperature for the 33 urban centres of the arid and semi-arid state of Rajasthan, India. Atmospheric Research 138, 73–90. DOI: http://dx.doi.org/10.1016/j.atmosres.2013.10.024.

Praveen, B., Talukdar, S., Shahfahad, Mahato, S., Mondal, J., Sharma, P., Islam, A.R.M., Rahman, A., 2020.

Analyzing trend and forecasting of rainfall changes in India using non-parametrical and machine learning approaches. Scientific Reports 10, 10342. DOI: https://doi.org/10.1038/s41598-020-67228-7.

Radhakrishnan, K., Sivaraman, I., Jena, S.K., Sarkar, S., Adhikari, S., 2017. A climate trend analysis of temperature and rainfall in India. Climate Change and Environmental Sustainability 5(2), 146–153. https://doi.org/ 10.5958/2320-642X.201700014.X.

Rathore, L.S., Attri, S.D., Jaswal, A.K., 2013. State level climate change trends in India. Indian Meteorological Department (GoI), New Delhi. https://climatechangecellodisha.org/pdf/STATE%20level%20climate%20change%20trends.pdf.

Saboohi, R., Soltani, S., Khodagholi, M., 2012. Trend analysis of temperature parameters in Iran. Theoretical and Applied Climatology 109(3–4), 529–547. DOI: https://doi.org/10.1007/s00704-012-0590-5.

Sarkar, K., Kumar, R.R., 2023. Spatial and temporal trend analysis for maximum and minimum temperature using non-parametric techniques. International Journal of Bio-resource and Stress Management 14(3), 465–478. https://doi.org/10.23910/1.2023.3371a.

Sen, P.K., 1968. Estimates of the regression coefficient based on Kendall's Tau. Journal of the American Statistical Association 63(324), 1379–1389. http://dx.doi.org/10.1080/01621459.1968.10480934.

Sen, Z., Sisman, E., Dabanli, I., 2019. Innovative polygon trend analysis (IPTA) and applications. Journal of Hydrology 575, 202–210. https://doi.org/10.1016/j.jhydrol.2019.05.028.

Tramblay, Y., Neppel, L., Carreau, J., Najib, K., 2013. Non stationary frequency analysis of heavy rainfall events in Southern France. Hydrological Sciences Journal 58(2), 280–294. DOI: https://doi.org/10.1080/02626667.2012.754988.

Yue, S., Hashino, M., 2003. Long term trends of annual and monthly precipitation in Japan. Journal of the American Water Resources Association 39(3), 587–596. https://doi.org/10.1111/j.1752-1688.2003.tb03677.x.