International Journal of Bio-resource and Stress Management https://pphouse.org/ijbsm.php

Crossref

IJBSM March 2023, 14(3):465-478 Print ISSN 0976-3988 Online ISSN 0976-4038 Article AR3371a

Research Article Natural Resource Management

DOI: HTTPS://DOI.ORG/10.23910/1.2023.3371a

Spatial and Temporal Trend Analysis for Maximum and Minimum Temperature Using Non-Parametric Techniques

Kader Ali Sarkar and Ravi Ranjan Kumar

Dept. of Agricultural Statistics, Institute of Agriculture, Visva-Bharati, Santiniketan, West Bengal (731 235), India

Open Access

Corresponding tan2ravi@gmail.com

0000-0001-6174-3295

ABSTRACT

A study on annual and seasonal (winter, spring, summer, and autumn) trend analysis of maximum and minimum temperature at the spatial and temporal scales had been carried out during January, 1981 to December, 2020 for agro-climatic zone-III of Bihar, India. Non-parametric statistical techniques viz. Mann-Kendall (MK) test with Sen's slope estimator, and Pettitt Mann–Whitney (PMW) test had been carried out to examine the annual and seasonal trends at 5% level of significance. The monthly air temperature (˚C) from the period January, 1981 to December, 2020 had been recorded for the spatial and temporal trend analysis. The results of the nonparametric tests showed statistically significant increasing trends in summer, autumn, and spring seasons for minimum temperature at most the spatial horizons while the trends for maximum temperature showed statistically non-significant decreasing trends at all the spatial horizons. The rate of change of the minimum temperature obtained from Sen's slope estimator was found to be higher in summer (0.021℃ year^{-1}), autumn (0.054˚C year^{-1}), and spring (0.041˚C year^{-1}) seasons at Bhojpur district. In case of the maximum temperature, the rate of change of temperature was observed to be higher in annual (-0.020℃ year^{-1}), winter (-0.012℃ year^{-1}), summer (-0.019˚C year^{-1}), and autumn (-0.013˚C year^{-1}) seasons. The most probable year of changes in the observed temperature were occurred in between 1992–2010. In conclusion, it was clear that the magnitudes of the minimum temperature trends and variability is greater than the maximum temperature for all 6 spatial horizons.

KEYWORDS: Non-parametric test, season, spatio-temporal variation, temperature, trend analysis

***Citation* (VANCOUVER):** Sarkar and Kumar, Spatial and Temporal Trend Analysis for Maximum and Minimum Temperature Using Non-Parametric Techniques. *International Journal of Bio-resource and Stress Management*, 2023; 14(3), 465-478. HTTPS://DOI.ORG/10.23910/1.2023.3371a.

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 16th December 2022 RECEIVED in revised form on 18th February 2023 ACCEPTED in final form on 05th March 2023 PUBLISHED on 21st March 2023

1. INTRODUCTION

Global climate change and its influence on patterns of weather parameters viz., temperature, rainfall, relative humidity, wind speed is apparent, and a serious threat to the sustainability and stability of any sectors. The impact of climate change is more in developing country like India in view of its huge population, rise in standard of living of population, industrialization, and excessive pressure on natural resources etc. The expected effects of climate change are already being felt in terms of rise in temperature, raising sea levels, hurricanes, tropical cyclones, heat waves, drought, and flood (Mandal et al., 2019), while on other hand it provides a favourable condition for vector-borne disease and also create breeding grounds for disease-carrying insects. According to Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (Anonymous, 2013), the global mean surface temperature is increasing quasi-linearly with cumulative greenhouse gas emission and strongly mentioned that the sea temperature is raised by 0.85℃ during 1880–2012, glaciers ice loss was about 226 Gt year^{-1} during 1971–2009, and mean sea level increased by 0.19 m during 1901–2010.According to Indian metrological department (IMD) reports (Rathore et al., 2013), in India the annual mean surface temperature has led to decreasing trend in northern states and led to no change in North–Eastern states, while lead to increasing trend in all other states during 1951–2010. As per latest report, annual mean surface air temperature of India has warmed by 0.6°C century^{-1} during 1901–2018 (Srivastava et al., 2019). Recently, the state of Bihar, there are numerous shreds of evidence showed that high temperature is responsible for the alteration of climate and groundwater levels increases with global warming while rising global temperatures are affecting the intensity and frequency of heatwaves and the incidence of extreme weather conditions like flooding in the north and droughts in south Bihar (Anonymous, 2019). Therefore, investigation of climate change at 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 trend in weather parameters over different spatial horizons would be helpful to the planners in the disaster adaptation and mitigation strategies.

In the recent past years, Parametric and nonparametric statistical tests like regression test (Haan, 2002), Mann-Kendall test (Mann, 1945, Kendall, 1973), Sen's slope estimation (Sen, 1968,Pingale et al., 2014), and Pettitt Mann-Whitney (PMW) test (Pettitt, 1979)have been used by many researchers to assess trends in weather parameters (Norbu and Basnet, 2022, Elzopy et al., 2020, Praveen et al., 2020, Chandole et al., 2019, Panda and Sahu, 2019, Bhuyan et al., 2018, Bera, 2017, 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. Hence, in this study, the trends of air temperature are detected using Mann–Kendall test with Sen's slope estimator, and Pettitt Mann–Whitney (PMW) test for annual and seasonal (winter, spring, summer, and autumn) maximum and minimum temperature in the different spatial horizons of Bihar. Keeping in view this discussion, there is a need for an objective methodology for trend analysis of weather parameters. 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.

2. MATERIALS AND METHODS

A Study on annual and seasonal trend analysis of maximum and minimum temperature at the spatial and temporal scales had been carried out during January, 1981 to December, 2020 for agro-climatic zone-III of Bihar, India.

2.1. Study area

The state of Bihar is situated at the Indo-Gangetic plains and lies between latitude 24°–27° N and longitude 82°–88° E with a total geographical area of 94,163 km^2. The climatic condition having sub-humid tropical climate and categorized into three agro-climatic zones viz. Zone-I (North-West Alluvial Plains), Zone-II (North-East Alluvial Plains), and Zone-III (South Alluvial Plain). The average temperature of the state ranges from 10°C in the winter to 34°C in the summer, with a weighted average annual rainfall of 1170 mm (Warwade et al., 2018). In the present study, total six districts of agro climatic Zone-III Figure(1) viz. Patna, Nalanda, Bhojpur, Rohtas, Jehanabad, and Aurangabad, had been considered for spatio-temporal trends analysis of air temperature from the period 1981–2020.

2.2. Source of data

Data used for the current study had been downloaded from NASA prediction of worldwide energy resources (Anonymous, 2021). Gridded data sets (0.5° latitude x 0.5° longitude spatial resolution) of monthly air temperature (***°C***) from the period January, 1981 to December, 2020 had been recorded for the spatial and temporal trend analysis. Further, the time series were segregated into five data sets viz. annual, and seasonal as characterized by the Indian Meteorological Department (IMD) guidelines: winter (Dec–Feb), spring (Mar–May), summer (June–Aug), and autumn (Sept–Nov).

2.3. Trend analysis

Statistically, a trend can be defined as a significant +/- changes in a random variable over time and estimated by using statistical parametric and non-parametric tests. In this study, non-parametric statistical methods were employed to trends analysis of air temperature. Mann-Kendall (MK) test, Sen slop estimator, and Pettitt Mann-Whitney (PMW) test had been used. The whole procedures were carried out on R programming.

2.4. Mann-Kendall (MK) test

Mann Kendall test had been used for the identifying trends in the spatio-temporal data. The advantage of non-parametric test over parametric test, it does not require the data to be normally distributed. The MK test statistics (S) can be computed as follows.

Null hypothesis (H_0): There is a no trend

Alternative hypothesis (H_1): There is a presence of trend

The Mann-Kendall test statistic (S):

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

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

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

For large samples (n>10), the test is conducted using a normal approximation (Z statistics) with the mean and the variance as follows:

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

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

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

$$Z=\begin{cases}S-1/\sqrt{(Var(S))} \text{ if } S>0\\ 0 \quad \text{if } S=0\\ S+1/\sqrt{(Var(S))} \text{ if } S<0\end{cases} \quad \ldots\ldots\ldots\ldots(5)$$

A significant trend is evaluated by the Z value which positive value of Z indicates an increasing trend and its negative value a decreasing trend. Null hypothesis (H_0) is tested at 5% level of significance ($Z_{0.05}$=1.96).

2.5. Sen's slope estimator

Sen's nonparametric approach was used to estimate the true slope of an existing trend (as change year^{-1}). When the trend can be considered to be linear, the Sen's technique can be utilised.

$$\beta=\text{Median}\,[(X\_j-X\_i)/(j-i)]\forall j>i\ p \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

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

2.6. Pettitt mann-whitney (PMW) test

The PMW test distinguishes the most likely change year in the yearly time series sequence. The PMW test statistics can be computed as follows;

Assume a time series $\{X_1, X_2,\ldots, X_n\}$ with a length n and where t is the time of the most likely change point. Two samples, $\{X_1, X_2,\ldots, X_t\}$ and $\{X_{t+1}, X_{t+2},\ldots, X_n\}$, can then be derived by dividing the time series at time t. An index, U_t, is derived as:

$$U_t=\sum_{i}^{t}1=\sum_{j=1}^{n} sgn(X_i-X_j) \quad \ldots\ldots\ldots.(7)$$

$$sgn(Xi-Xj)\begin{cases}+1 \text{ if } (X_i-X_j)>0\\ 0 \text{ if} (X_i-X_j)=0\\ -1 \text{ if}(X_i-X_j)<0\end{cases} \quad \ldots\ldots\ \ldots.(8)$$

A plot of against t for a time series with no change point would result in a continually increasing value of . However, if there is a change point (even a local change point) then would increase up to the change point and then begin to decrease. This increase followed by a decrease may occur several times in a time series, indicating several local change points. So, there is still the question of determining the most significant change point. We can identify the most significant change point where the value of $|U_t|$ is maximum.

$$K_t=\max_{1\leq t\leq T}|U_t| \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots.(9)$$

The approximated significance probability $P(t)$ for a change point is given as:

$$P=1-exp\left[\frac{-6K_t^2}{n^3+n^2}\right] \quad \ldots\ldots\ldots\ldots\ldots.(10)$$

The change point is statistically significant at the time t with a significance level of α when probability $P(t)$ exceeds 1 − α.

3. RESULTS AND DISCUSSION

3.1. Temperature variability

The descriptive statistics of annual and seasonal (winter, spring, summer, and autumn) maximum temperature and minimum temperature had been computed such as the mean, standard deviation (SD), coefficient of variation (CV) which are discussed in Tables 1 to 6. Temperature variability patterns over 1981–2020 for six districts of agro

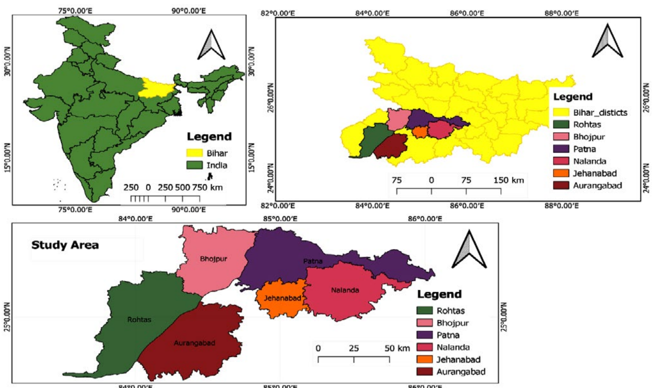

Figure 1. Study area of agro climatic Zone-III, Bihar, India

Table 1: Descriptive statistical trend analysis of temperature for Nalanda district

Seasons	Nalanda district					
	Maximum temperature			Minimum temperature		
	Mean (˚C)	Standard deviation	CV (%)	Mean (˚C)	Standard deviation	CV (%)
Annual	46.12	1.07	2.33	4.71	1.17	24.79
Summer	39.16	1.44	3.68	25.19	0.52	2.08
Autumn	32.03	1.17	3.66	15.90	1.08	6.77
Winter	29.53	1.17	3.95	6.30	0.76	12.00
Spring	42.92	0.99	2.31	18.05	1.15	6.39

Table 2: Descriptive statistical trend analysis of temperature for Jehanabad district

Seasons	Jehanabad district					
	Maximum temperature			Minimum temperature		
	Mean	Standard Deviation	CV (%)	Mean (˚C)	Standard Deviation	CV (%)
Annual	46.72	1.11	2.37	4.83	1.20	24.90
Summer	39.60	1.52	3.85	25.30	0.55	2.16
Autumn	32.23	1.25	3.89	15.85	1.08	6.83
Winter	30.09	1.11	3.67	6.39	0.79	12.30
Spring	43.58	0.97	2.24	18.24	1.14	6.24

climatic zone-III in Bihar using the coefficient of variation (CV) indicates that the inter-annual variation of minimum temperature was higher than of maximum temperature. In case of summer temperature, there was slightly variation observed in the maximum and minimum temperatures. The mean annual maximum temperature for Patna, Nalanda, Bhojpur, Rohtas, Jehanabad, and Aurangabad districts have been observed of 46.57˚C, 46.12˚C, 46.84˚C, 46.33˚C, 46.72˚C, and 46.92˚C, respectively and mean annual minimum temperature for Patna, Nalanda, Bhojpur, Rohtas, Jehanabad had been observed of 4.63˚C, 4.71˚C,

Table 3: Descriptive statistical trend analysis of temperature for Bhojpur district

Seasons	Bhojpur district					
	Maximum temperature			Minimum temperature		
	Mean	Standard deviation	CV (%)	Mean (˚C)	Standard deviation	CV (%)
Annual	46.84	1.12	2.40	4.66	1.11	23.80
Summer	39.74	1.55	3.90	25.54	0.59	2.31
Autumn	32.55	1.36	4.18	15.73	1.13	7.17
Winter	30.08	1.20	3.99	6.19	0.76	12.28
Spring	43.77	0.94	2.15	18.22	1.15	6.32

Table 4: Descriptive statistical trend analysis of temperature for Aurangabad district

Seasons	Aurangabad district					
	Maximum temperature			Minimum temperature		
	Mean (˚C)	Standard Deviation	CV (%)	Mean (˚C)	Standard Deviation	CV (%)
Annual	46.92	1.07	2.29	5.28	1.18	22.26
Summer	39.59	1.54	3.89	25.28	0.53	2.11
Autumn	32.41	1.33	4.11	15.92	1.07	6.72
Winter	30.65	1.01	3.30	6.86	0.79	11.59
Spring	43.86	0.96	2.18	18.49	1.07	5.79

Table 5: Descriptive statistical trend analysis of temperature for Rohtas district

Seasons	Rohtas district					
	Maximum temperature			Minimum temperature		
	Mean (˚C)	Standard Deviation	CV (%)	Mean (˚C)	Standard Deviation	CV (%)
Annual	46.33	0.91	1.95	5.21	1.24	23.78
Summer	38.72	1.57	4.04	24.36	0.54	2.20
Autumn	31.42	1.17	3.72	15.33	0.95	6.20
Winter	30.29	1.20	3.96	6.73	0.97	14.44
Spring	43.22	0.94	2.16	18.28	1.15	6.30

Table 6: Descriptive statistical trend analysis of temperature for Patna district

Seasons	Patna district					
	Maximum temperature			Minimum temperature		
	Mean (°C)	Standard Deviation	CV (%)	Mean (°C)	Standard Deviation	CV (%)
Annual	46.57	1.13	2.43	4.63	1.12	24.12
Summer	39.55	1.53	3.87	25.53	0.56	2.21
Autumn	32.58	1.38	4.23	15.86	1.11	7.02
Winter	29.98	1.19	3.99	6.13	0.76	12.47
Spring	43.59	0.94	2.15	18.18	1.17	6.42

4.66°C, 5.21°C, 4.83°C, and 5.28°C, respectively. Overall, there had been high variation recorded in annual minimum temperature throughout years in all six districts.

3.2. Non-parametric trend analysis

In this section, non-parametric methods were applied for temperature trends analysis in agro climatic zone-III of Bihar. MK test, Sen's slope estimator, and PMW test were used to trend analysis of annual and seasonal temperature. The direction (*Z* value), estimate of the trend and probability change point (K_t) for annual and seasonal (winter, spring, summer, and autumn) maximum temperature and minimum temperature for six districts of Bihar during 1981–2020 and reported in Tables 7 to 8. Positive and negative values indicated the increasing and decreasing trends respectively. The trend plots for annual and seasonal rainfall are represented in Figures 2 to 13.

The annual and seasonal maximum temperature showed statistically non-significant decreasing trends for all 6 spatial horizons during 1981–2020. It can be also seen from the trend plots of maximum temperature. The magnitude of the maximum temperature trends obtained from Sen's slope estimator was observed the highest in annual (-0.020°C year^{-1}) and winter (-0.012°C year^{-1}) seasons in Patna. In case of summer (-0.019°C year^{-1}) and autumn (-0.013°C year^{-1}) seasons, the highest maximum temperature was observed in Jehanabad. Similarly, in spring (-0.021°C year^{-1}) season, the highest Sen's slope estimate was observed in Nalanda. The most probable year of changes in the observed annual and autumn maximum temperature trends were shifted in 1999 and 1992 for each district, respectively. In the case of summer, winter, and spring seasons, the probable year of changes were shifted in 1996, 1994 and 2005 at the most of districts, respectively.

Table 7: Non-parametric statistical trend analysis of temperature for Aurangabad district

Seasons	Aurangabad district					
	Maximum temperature			Minimum temperature		
	MK test (Z value)	Sen's slope estimate	PMW test (Kt)	MK test (Z value)	Sen's slope estimate	PMW test (Kt)
Annual	-0.070^{NS}	-0.001	1999	-1.748^{NS}	-0.033	2010
Summer	-0.536^{NS}	-0.016	1996	1.783^{NS}	0.016	2008
Autumn	-0.443^{NS}	-0.009	1992	3.799*	0.050	1996
Winter	-0.431^{NS}	-0.008	1994	-0.396^{NS}	-0.006	2009
Spring	-0.699^{NS}	-0.011	2005	2.412*	0.039	1999

*& NS indicates the significant and non-significant at (p=0.05) respectively

Table 8: Non-parametric statistical trend analysis of temperature for Nalanda district

Seasons	Nalanda district					
	Maximum temperature			Minimum temperature		
	MK test (Z value)	Sen's slope estimate	PMW test (Kt)	MK test (Z value)	Sen's slope estimate	PMW test (Kt)
Annual	-1. 328^{NS}	-0. 018	1999	-1.131^{NS}	-0.015	2009
Summer	-0. 583^{NS}	-0. 014	1996	2.098*	0.015	2008
Autumn	-0. 758^{NS}	-0. 010	1992	3.216*	0.046	1996
Winter	-0. 454^{NS}	-0. 009	1994	-0.629^{NS}	-0.007	2011
Spring	-1. 293^{NS}	-0. 021	2004	2.505*	0.036	1998

*& NS indicates the significant and non-significant at (p=0.05) respectively

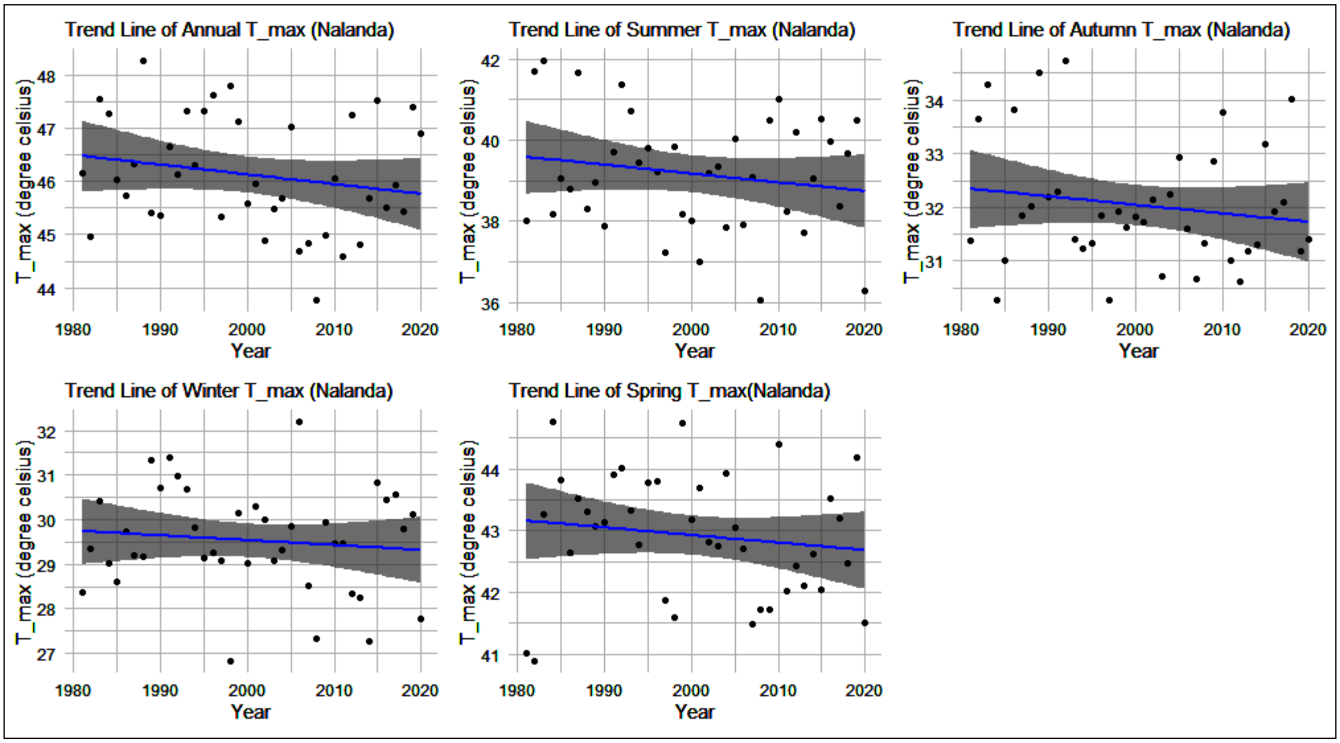

Figure 2. Annual and seasonal trend plots in the maximum temperature in the Nalanda district

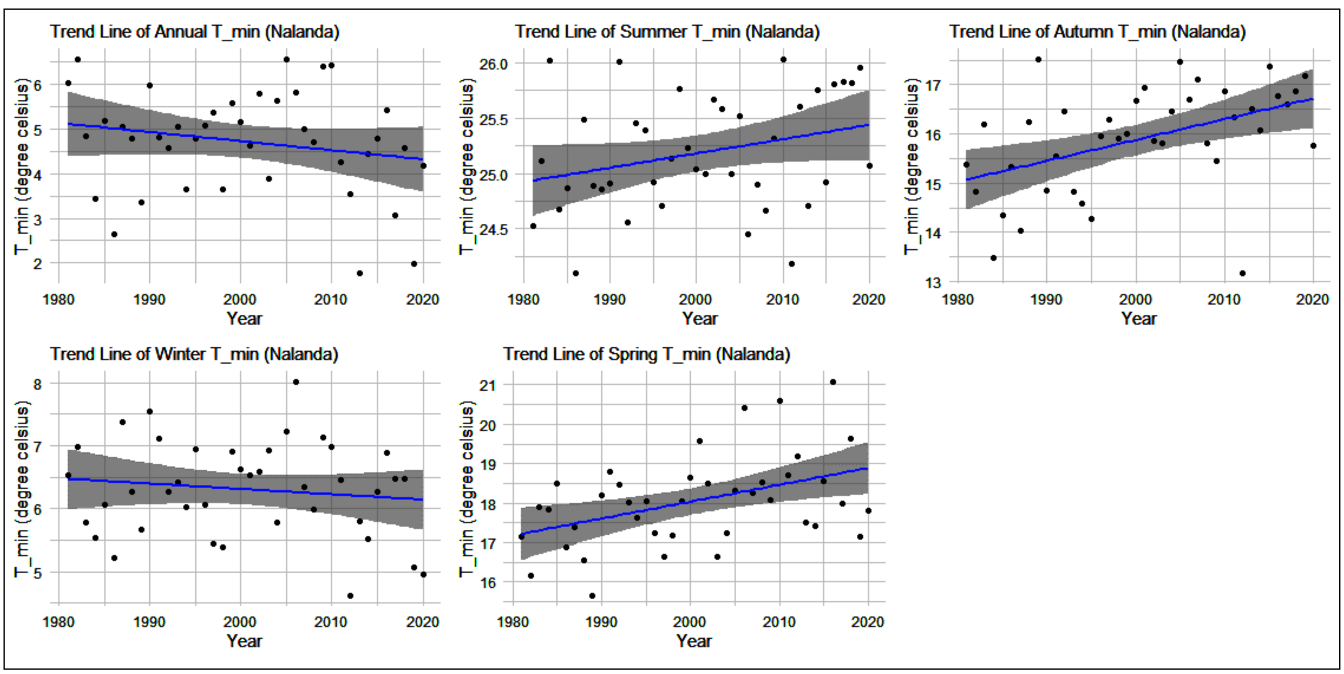

Figure 3. Annual and seasonal trend plots in the minimum temperature in the Nalanda district

The minimum temperature showed statistically significant increasing trends in summer in Nalanda, Bhojpur, and Patna. In autumn season, all six regions were observed significant increasing trends and in spring season also observed significant increasing trends (except Rohats district) while in winter and annual seasons temperature were observed non-significant decreasing trends in all 6 districts. It can be also seen from the trends plots of minimum temperature. The highest increasing rates were observed in summer (0.021°***C year***$^{-1}$), autumn (0.054°***C year***$^{-1}$), and spring (0.041°***C year***$^{-1}$) seasons in Bhojpur districts while the highest decreasing rates were observed

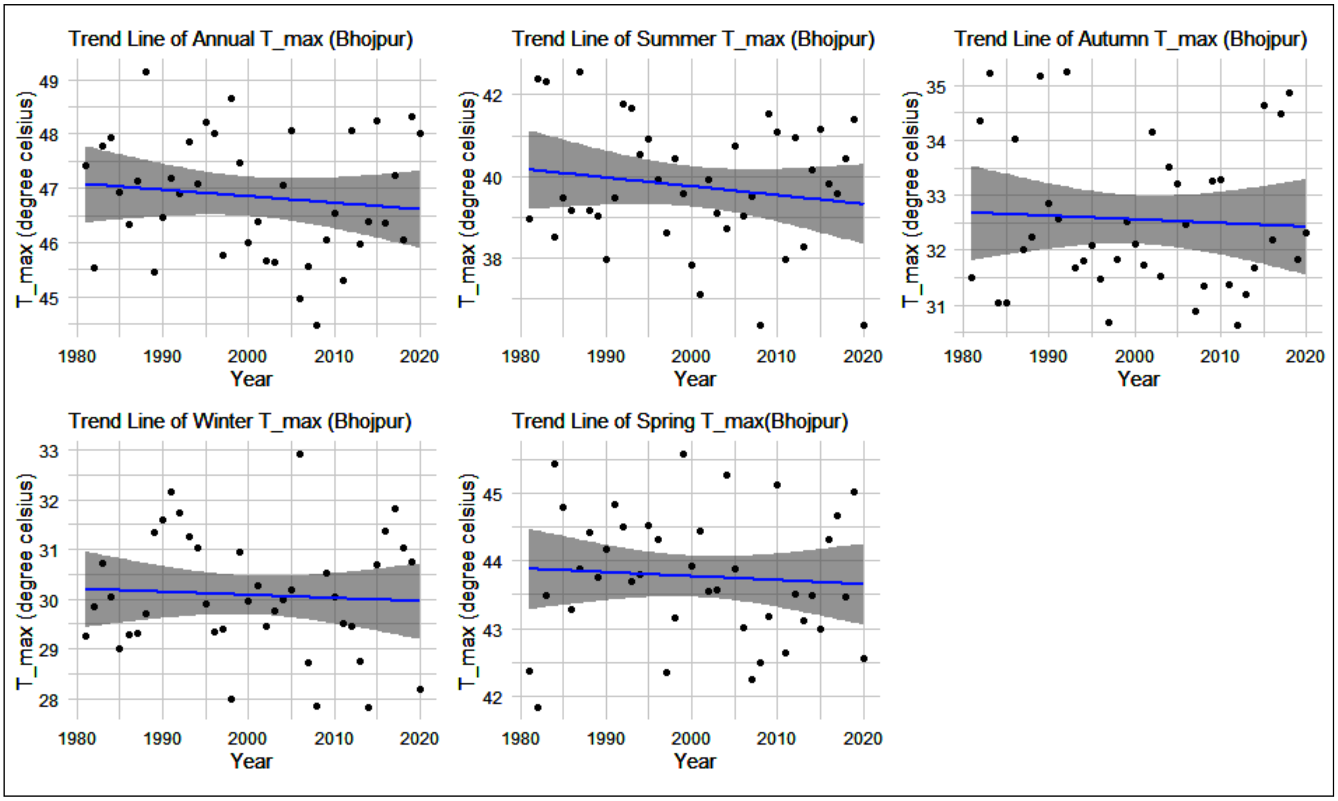

Figure 4: Annual and seasonal trend plots in the maximum temperature in the Bhojpur district

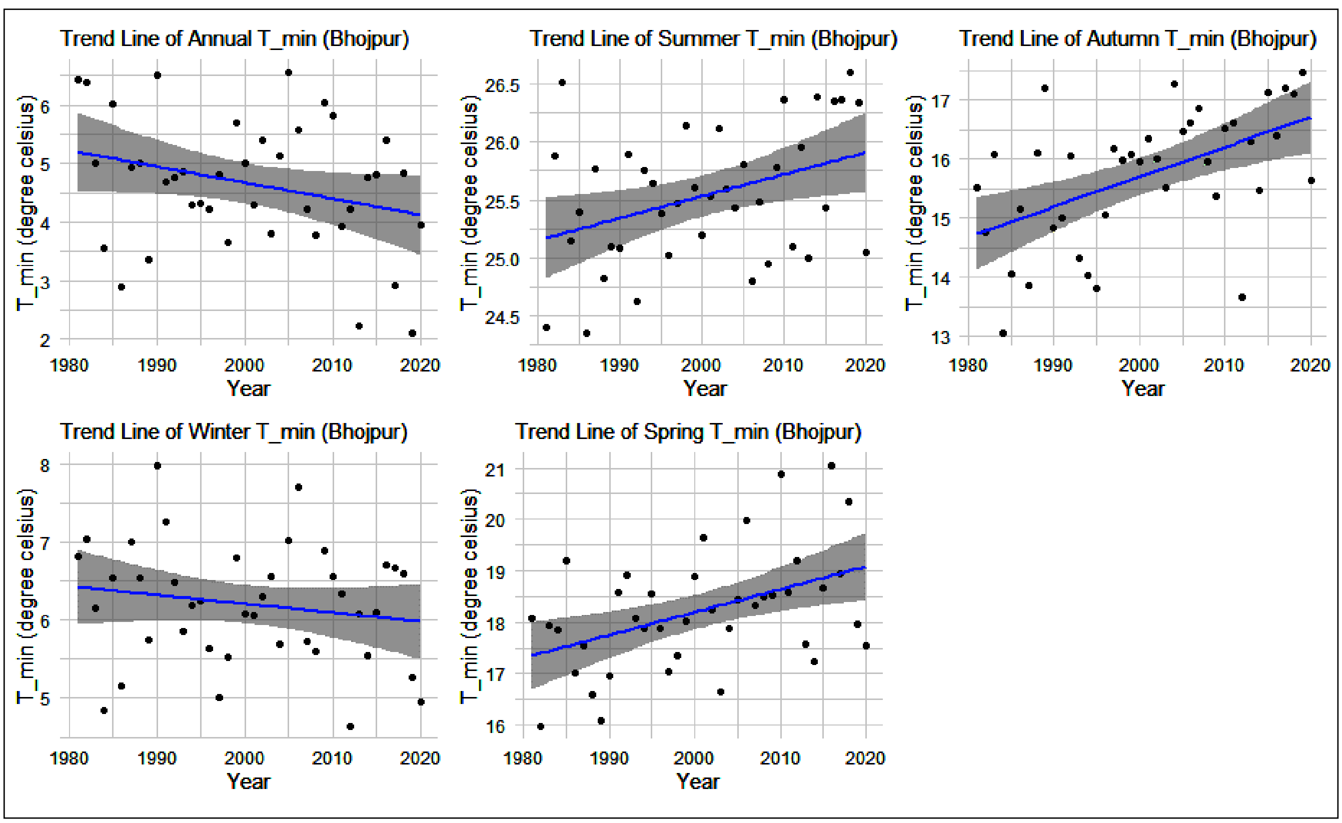

Figure 5: Annual and seasonal trend plots in the minimum temperature in the Bhojpur district

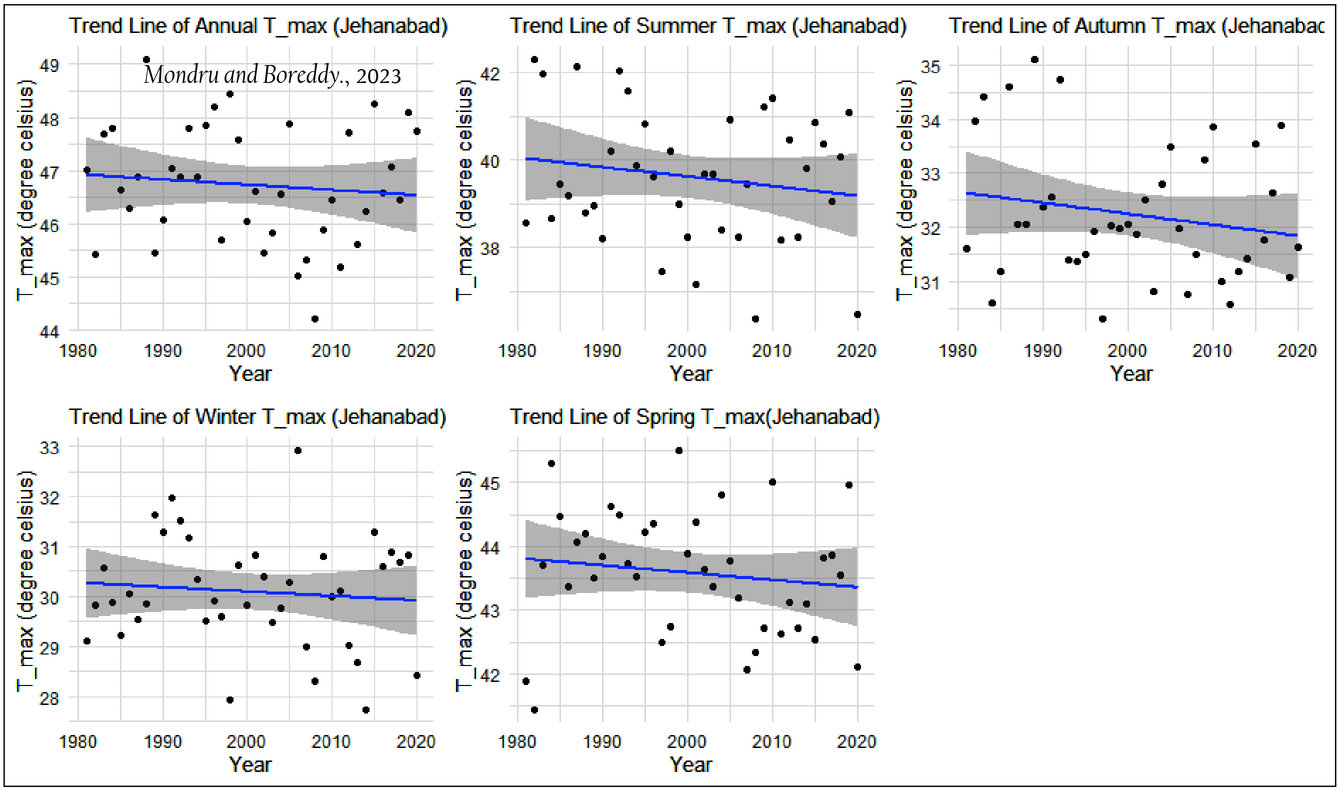

Figure 6. Annual and seasonal trend plots in the maximum temperature in the Jehanabad district

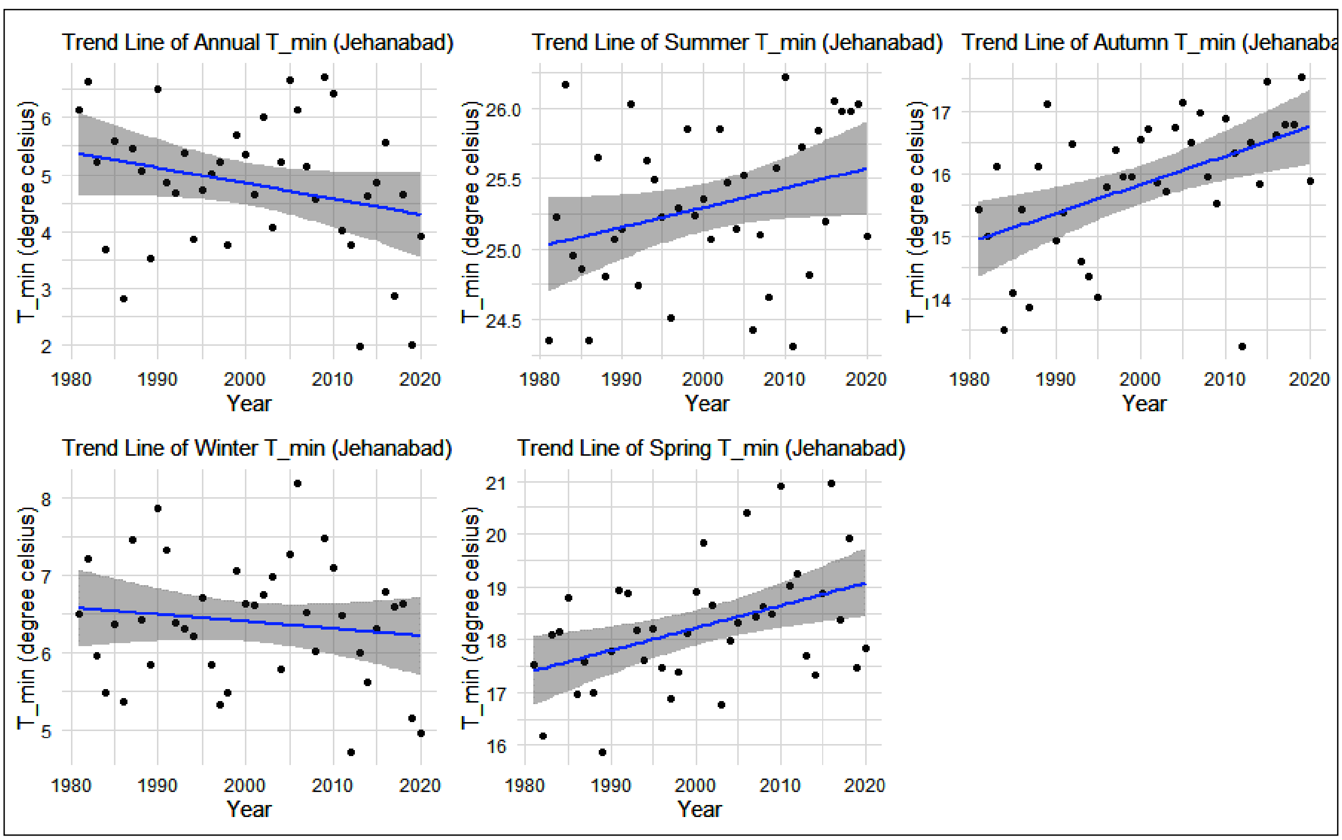

Figure 7: Annual and seasonal trend plots in the minimum temperature in the Jehanabad district

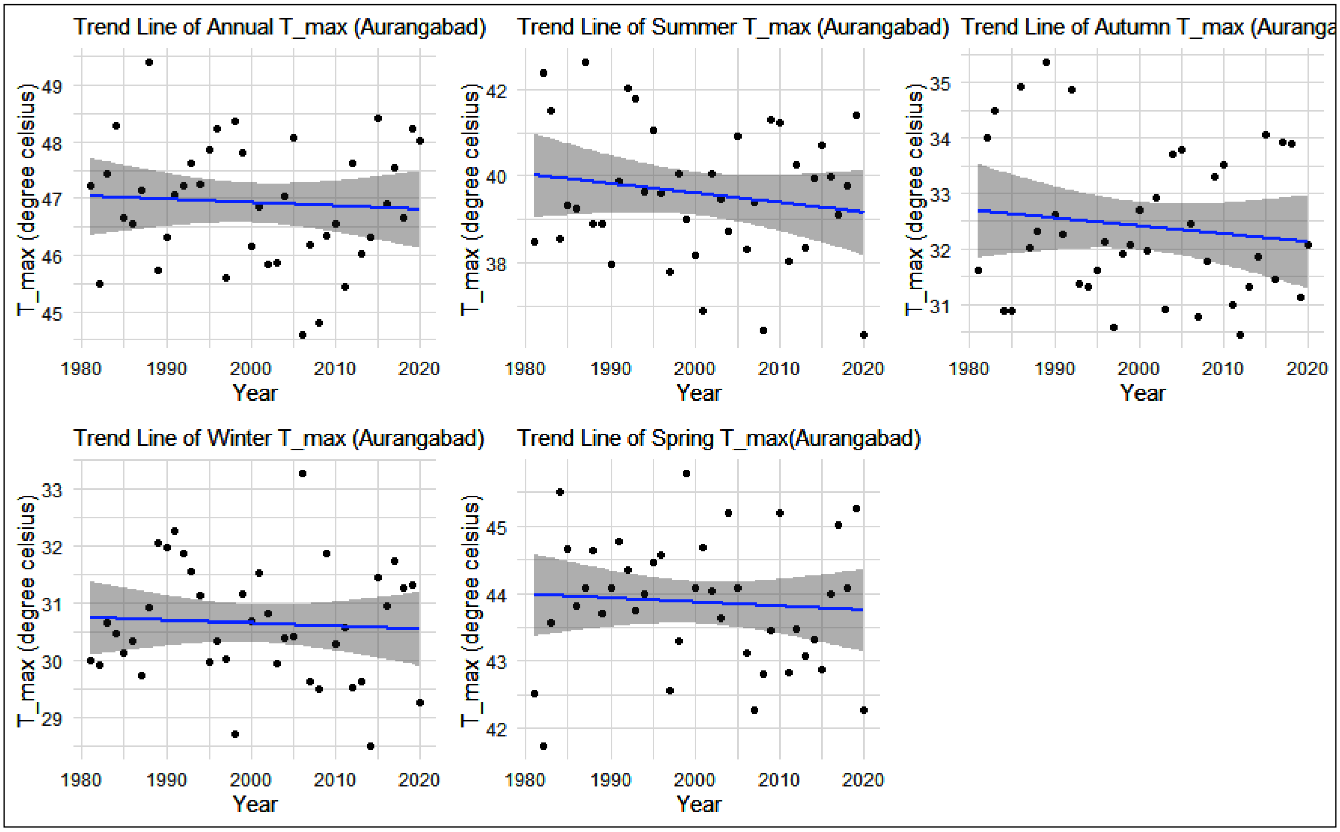

Figure 8. Annual and seasonal trend plots in the maximum temperature in the Aurangabad district

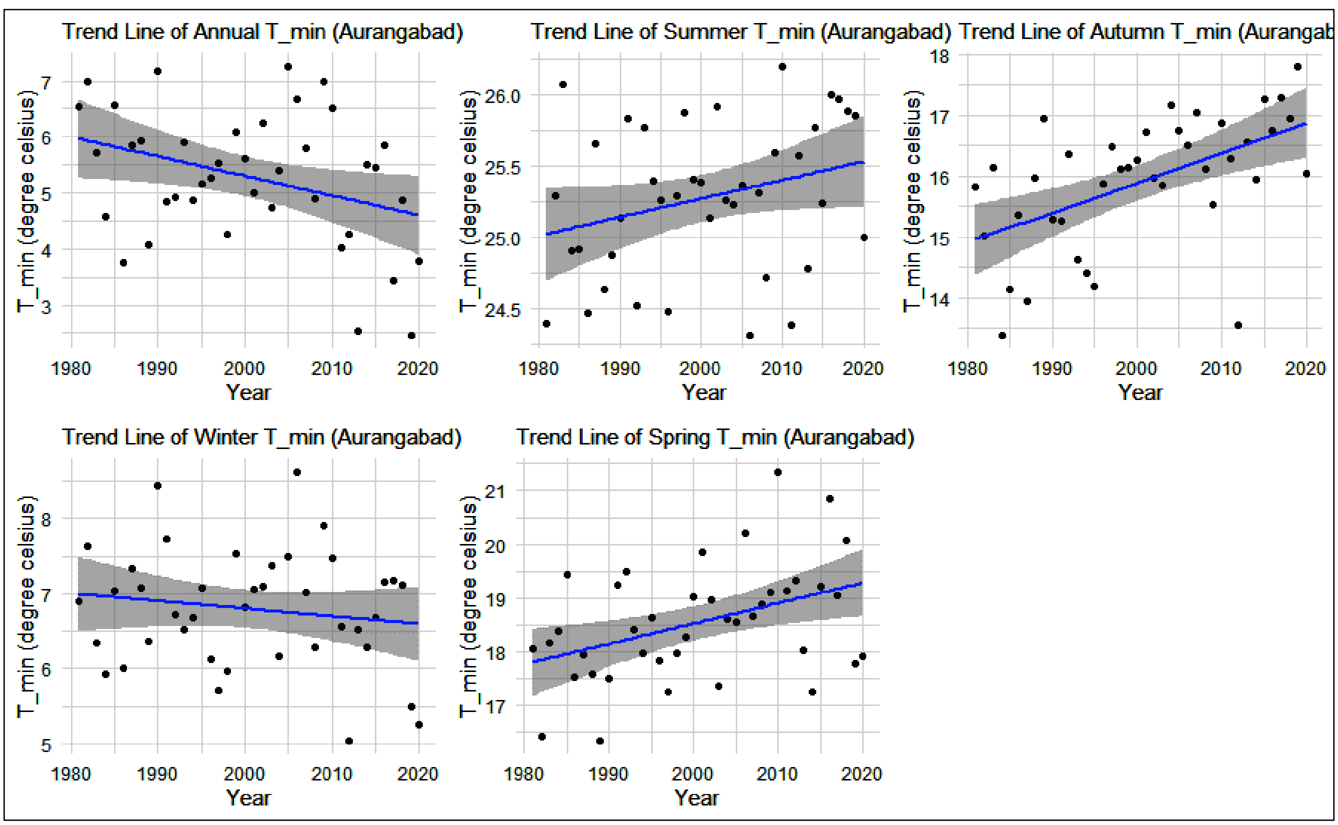

Figure 9. Annual and seasonal trend plots in the minimum temperature in the Aurangabad district

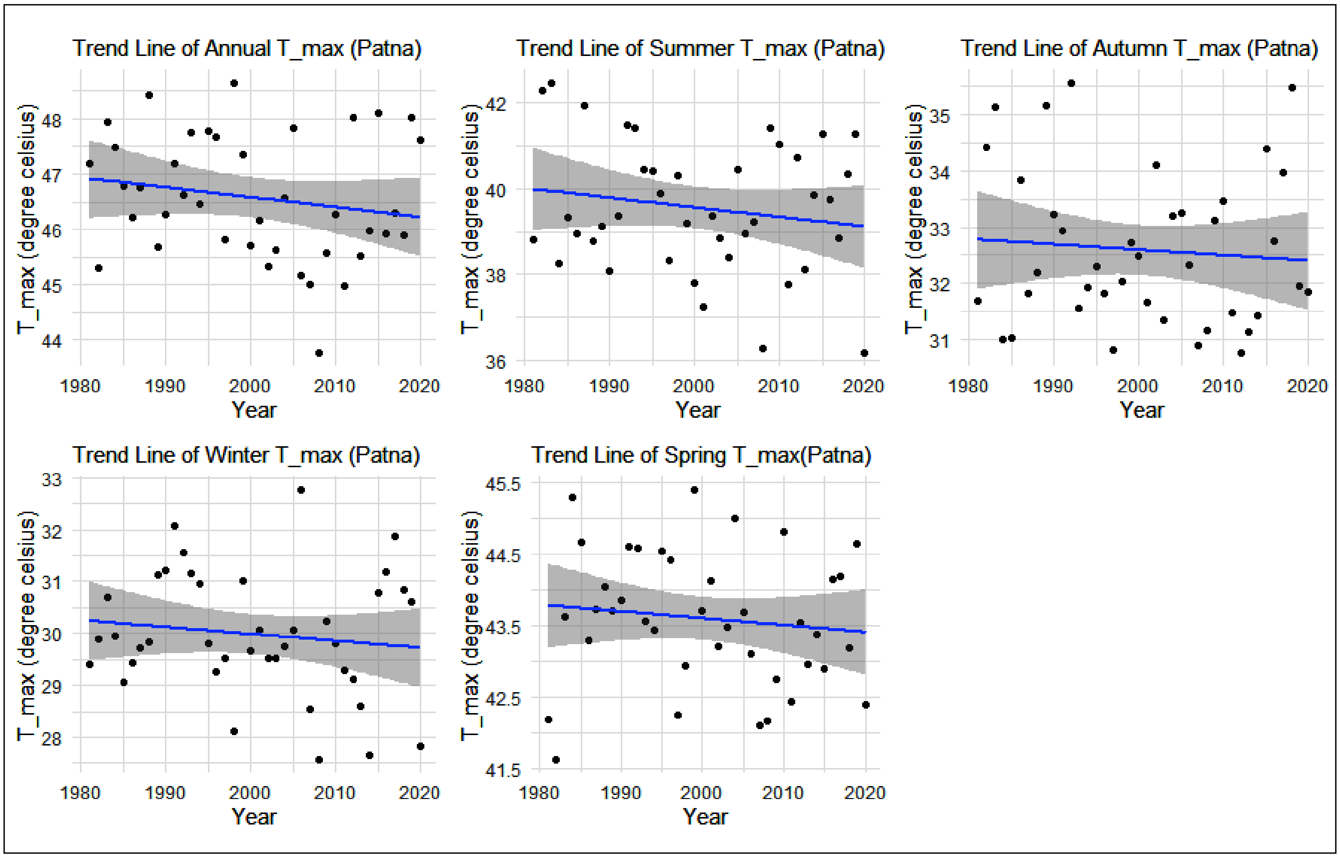

Figure 10: Annual and seasonal trend plots in the maximum temperature in the Patna district

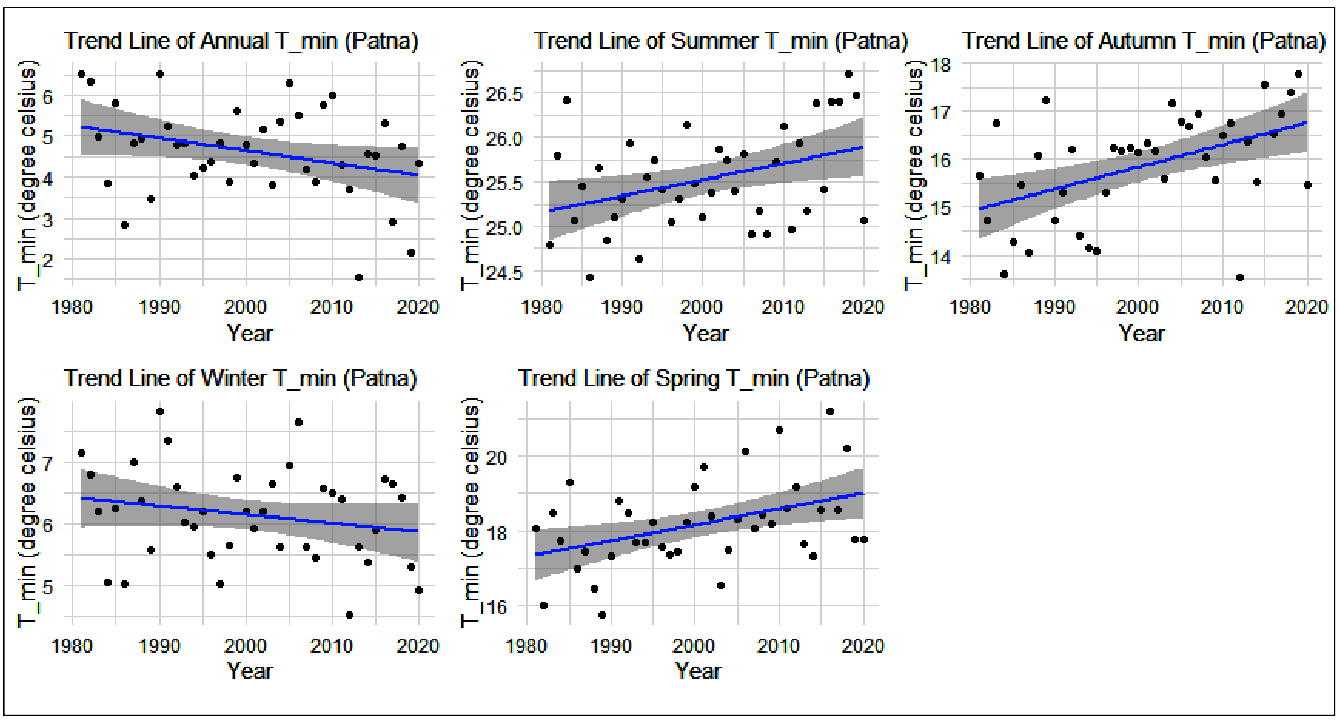

Figure 11: Annual and seasonal trend plots in the minimum temperature in the Patna district

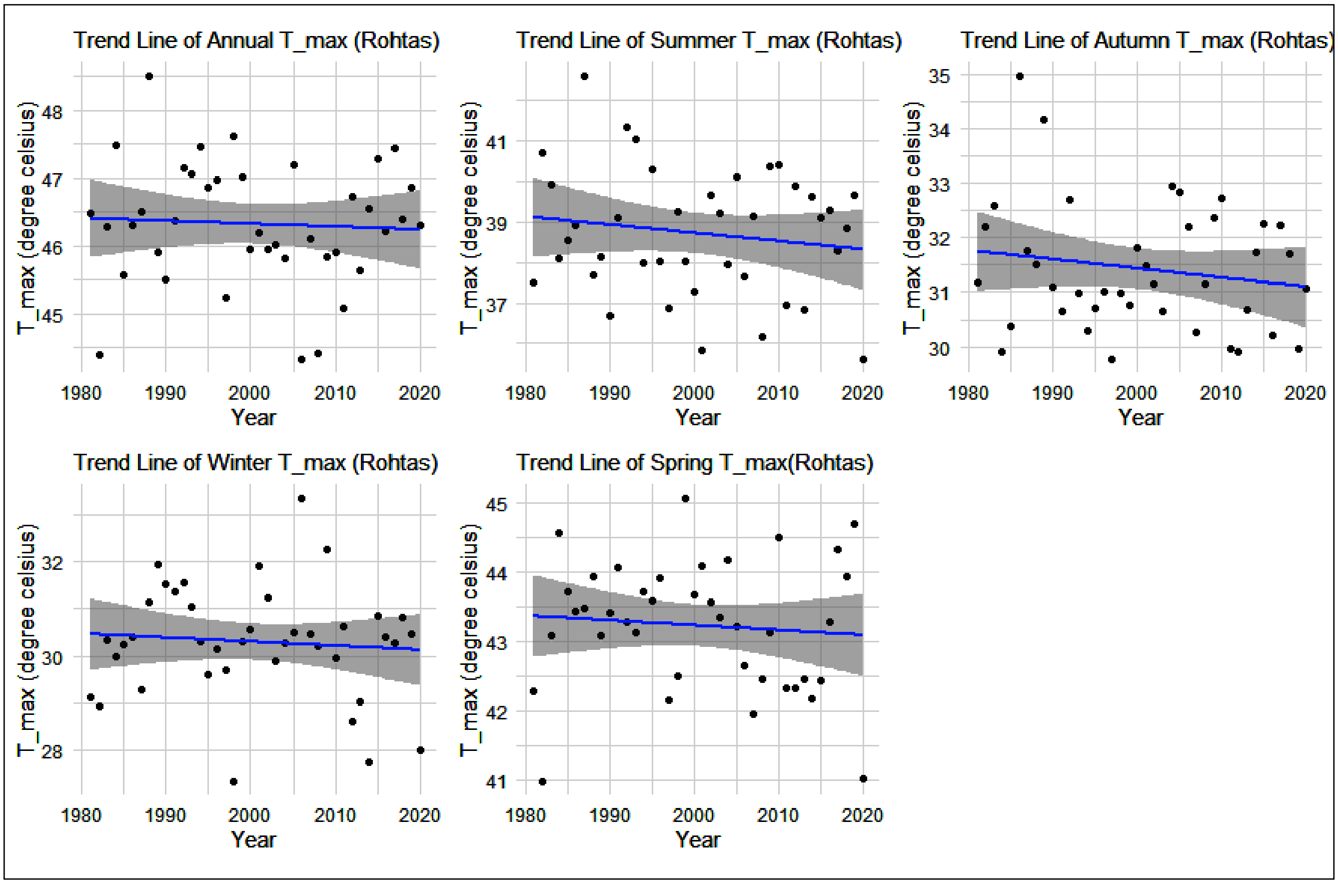

Figure 12. Annual and seasonal trend plots in the maximum temperature in the Rohtas district

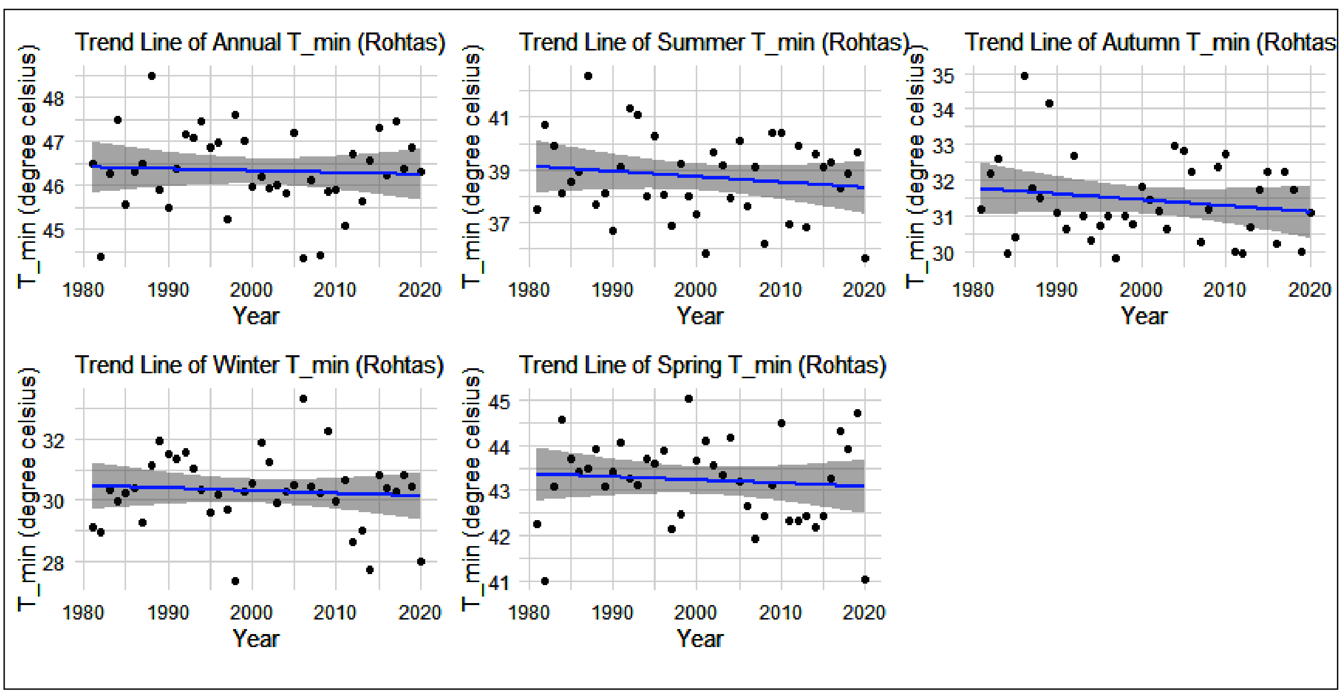

Figure 13. Annual and seasonal trend plots in the minimum temperature in the Rohtas district

Table 9: Non-parametric statistical trend analysis of temperature for Bhojpur district

Seasons	Bhojpur district					
	Maximum Temperature			Minimum Temperature		
	MK test (Z value)	Sen's slope estimate	PMW test (Kt)	MK test (Z value)	Sen's slope estimate	PMW test (Kt)
Annual	-0.454[NS]	-0.010	1999	-1.527[NS]	-0.027	2009
Summer	-0.455[NS]	-0.015	1996	2.063*	0.021	2008
Autumn	-0.117[NS]	-0.005	1992	3.438*	0.054	1996
Winter	0.058[NS]	0.001	1998	-1.014[NS]	-0.013	1992
Spring	-0.792[NS]	-0.011	2005	2.738*	0.041	1999

*&NS indicates the significant and non-significant at (p=0.05) respectively

Table 10: Non-parametric statistical trend analysis of temperature for Jehanabad district

Seasons	Jehanabad district					
	Maximum Temperature			Minimum Temperature		
	MK test (Z value)	Sen's slope estimate	PMW test (Kt)	MK test (Z value)	Sen's slope estimate	PMW test (Kt)
Annual	-0.478[NS]	-0.008	1999	-1.503[NS]	-0.026	2009
Summer	-0.629[NS]	-0.019	1995	1.888[NS]	0.019	2008
Autumn	-0.816[NS]	-0.013	1992	3.439*	0.047	1996
Winter	-0.256[NS]	-0.005	1994	-0.536[NS]	-0.009	2011
Spring	-1.165[NS]	-0.019	2005	2.575*	0.039	1999

*&NS indicates the significant and non-significant at (p=0.05) respectively

Table 11: Non-parametric statistical trend analysis of temperature for Patna district

Seasons	Patna district					
	Maximum temperature			Minimum temperature		
	MK test	Sen's slope estimate	PMW test (Kt)	MK test (Z value)	Sen's slope estimate	PMW test (Kt)
Annual	-1.165[NS]	-0.020	1999	-1.760[NS]	-0.024	2009
Summer	-0.699[NS]	-0.018	1996	2.250*	0.019	2008
Autumn	-0.291[NS]	-0.007	1992	3.239*	0.051	1996
Winter	-0.676[NS]	-0.012	1994	-1.398[NS]	-0.016	2006
Spring	-1.095[NS]	-0.016	2005	2.401*	0.036	1998

*& NS indicates the significant and non-significant at (p=0.05) respectively

in annual (-0.033°C year^{-1}) and winter (-0.016°C year^{-1}) seasons in Aurangabad and Patna, respectively. The most probable year of changes in the observed minimum annual and autumn temperature trends were shifted in 2010 and 1996 for each districts, respectively. In the case of summer, winter, and spring seasons, the probable year of changes were shifted in 1997, 2011, and 1999 at most of the districts, respectively. The increases trend of seasonal minimum temperature was also observed in India by Jain et al. (2013). In conclusion, it was cleared that the magnitudes of the minimum temperature trends and variability is higher than the maximum temperature for all six spatial horizons. It might be due to natural and anthropogenic forcing such as land-use and land cover including agriculture pattern, urbanization, deforestation etc.

Table 12: Non-parametric statistical trend analysis of temperature for Rohtas district

Seasons	Rohtas district					
	Maximum temperature			Minimum temperature		
	MK test (Z value)	Sen's slope estimate	PMW test (Kt)	MK test (Z value)	Sen's slope estimate	PMW test (Kt)
Annual	-0.233^{NS}	-0.003	1999	-1.737^{NS}	-0.030	2009
Summer	-0.676^{NS}	-0.015	1995	1.911^{NS}	0.015	1997
Autumn	-0.688^{NS}	-0.012	1992	3.717*	0.046	1996
winter	-0.140^{NS}	-0.002	1987	-0.524^{NS}	-0.010	2011
Spring	-0.653^{NS}	-0.010	2004	1.841^{NS}	0.032	1999

*&NS indicates the significant and non-significant at 5% respectively

4. CONCLUSION

Non-parametric approaches had been used to trends analysis of annual and seasonal maximum and minimum temperatures for six different spatial horizons of Bihar. The results showed statistically significant increasing trends in summer, autumn, and spring seasons for minimum temperature while the results of the maximum temperature trends were observed statistically non-significant decreasing trends at all six districts. Therefore, this work may give a clear and useful information regarding annual and seasonal temperature trends at different spatial horizons of Bihar.

5. ACKNOWLEDGEMENT

We are grateful to the department of Agricultural Statistics, Visva-Bharati University for all sort of assistance provided during this study.

6. REFERENCES

Anonymous, 2013. Climate change: Impacts, adaptation, and vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), Summary for policymakers. Available at https://www.ipcc.ch/report/ar5/wg1/. Accessed on 14th January, 2022.

Anonymous, 2019. Bihar faces double whammy: flood as well as drought. Deccan Herald. Available at https://www.deccanherald.com/national/bihar-faces-double-whammy-flood-as-well-as-drought 754758. htmlhttps://www.deccanherald.com/national/bihar-faces-double-whammy-flood-as-well-as-drought-754758. Accessed on 16th August, 2019.

Anonymous, 2021. NASA prediction of worldwide energy resources. (https://power.larc.nasa.gov/data-access-viewer/). Accessed on 16th August, 2021.

Bera, S., 2017. Trend analysis of rainfall in Ganga basin, India during 1901–2000. American Journal of Climate Change 6, 116–131. DOI: https://doi.org/ 10.4236/ajcc.2017.61007.

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. DOI: https://doi.org/10.3390/cli2030206.

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.

Elzopy, Karam A., Ashish, K., Chaturvedi, K., Chandran, M., Gopinath, 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. DOI: https://doi.org/10.1080/037 36245.2020.1835699.

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. DOI: https://doi.org/10.1175/JAMC-D-15-0265.1.

Haan, C.T., 2002. Statistical Methods in Hydrology (2nd Edn). Iowa State University Press, Ames, Iowa, 496.

Jain, S.K., Kumar, V., Saharia, M., 2013. Analysis of rainfall and temperature trends in Northeast India. International Journal of Climatology 33(4), 968–978. DOI: https://doi.org/10.1002/joc.3483.

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.

Kendall, M.G., 1973. Time Series. Charles Griffin and Co. Ltd., London.

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.

Mann, H.B., 1945. Non-parametric tests against trend. Econometrica 13, 163–171.

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. DOI: 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 DOI: 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. DOI: https://doi.org/10.1002/asl.932.

Pettitt, A.N., 1979. A non-parametric approach to the change point problem. Journal of the Royal Statistical Society, Series C. Applied Statistics 28, 126–135. DOI: https://doi.org/10.2307/2346729.

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. DOI: 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, Available at http://environicsindia.in/wp-content/uploads/2018/09/StateLevelClimateChangeMonoFinal.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.

Sen, P.K., 1968. Estimates of the regression coefficient based on Kendall's tau. Journal of the American Statistical Association 63, 1379–1389.

Srivastava, A.K., Revadekar J.V., Rajeevan M., 2019. South Asia in "State of the climate in 2018". Bulletin American Meteorological Society 100(9), S236–S240. DOI: https://doi.org/10.1175/2019BAMSStateoftheClimate.1.

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.

Warwade, P., Tiwari, S., Ranjan, S., Chandniha, S.K., Adamowski, J., 2018. Spatial-temporal variation of rainfall over Bihar State, India. Journal of Water and Land Development 36 (I–III), 183–197. DOI: https://doi.org/10.2478/jwld-2018-0018.

Yavuz, H., Erdogan, S., 2012. Spatial analysis of monthly and annual precipitation trends in Turkey. Water Resource Management 26(3), 609–621. DOI: https://doi.org/10.1007/s11269-011-9935-6.