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RESEARCH ARTICLE

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Trend analysis of seasonal rainfall and temperature pattern in Kalahandi, Bolangir and Koraput districts of Odisha, India

Arpita Panda[1] | **Netrananda Sahu**[1,2]

[1]Department of Geography, Delhi School of Economics, University of Delhi, Delhi, India

[2]Disaster Prevention Research Institute, Kyoto University, Kyoto, Japan

Correspondence
Netrananda Sahu, Department of Geography, Delhi School of Economics, University of Delhi, Delhi 110007, India.
Email: babunsahu@gmail.com

Abstract

Climate variability, particularly that of the annual air temperature and rainfall, has received a great deal of attention worldwide. The magnitude of the variability or fluctuations of the factors varies according to locations. Hence, examining the spatiotemporal dynamics of meteorological variables in the context of changing climate, particularly in countries where rainfed agriculture is predominant, is vital to assess climate-induced changes and suggest feasible adaptation strategies. To that end, the present study examines long-term changes and short-term fluctuations in monsoonal rainfall and temperature over Kalahandi, Bolangir and Koraput (hereafter KBK) districts in the state of Odisha. Both rainfall and temperature data for period of 1980–2017 were analyzed in this study. Statistical trend analysis techniques namely Mann–Kendall test and Sen's slope estimator were used to examine and analyze the problems. The detailed analysis of the data for 37 years indicate that the annual maximum temperature and annual minimum temperature have shown an increasing trend, whereas the monsoon's maximum and minimum temperatures have shown a decreasing trend. Statistically significant trends are detected for rainfall and also the result is statistically significant at 99% confidence limit during the period of 1980–2017. Rainfall is showing a quite good increasing trend (Sen's slope = 4.034) for JJAS season. In the case of maximum temperature for the observed period, it showed a slight warming or increasing trend (Sen's slope = 0.29) while the minimum temperature trend showed a cooling trend (Sen's slope = −0.006) but result of maximum temperature trend analysis is statistically significant at 95% confidence limit, on the contrary, the trend analysis result of minimum temperature is not statistically significant.

KEYWORDS

climate variability, Mann–Kendall's test, Sen's slope estimator, trend analysis

1 | INTRODUCTION

Climate is one of the key components in the earth system. There are many variables such as temperature, rainfall, atmospheric pressure, humidity that constitute weather and climate. Climate is usually defined as the average weather. In broad sense, it is the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years (IPCC, 2007). The analysis of long-term changes in climatic variables is a fundamental task in studies on climate change detection. The understanding of past and recent climate change has received considerable attention through improvements and extensions of numerous datasets and more sophisticated data analyses across the globe (Kumar *et al.,* 2010). Global climate changes may influence long-term rainfall patterns impacting the availability of water, along with the danger of increasing occurrences of droughts and floods (Pal and Mishra, 2017). The rainfall and temperatures (Singh *et al.,* 2013) are the most important fundamental physical parameters among the climate as these parameters determine the environmental condition of the particular region which affects the agricultural productivity (Modarres and da Silva, 2007; Kumar and Gautam, 2014). Agriculture and other related sectors, food security and energy security of any region are crucially dependent on the timely availability of adequate amount of water and a conducive climate. The rainfall received in an area is an important factor in determining the amount of water available to meet various demands such as agricultural, industrial, domestic water supply and for hydroelectric power generation. The pattern and amount of the rainfall (Gajbhiye *et al.,* 2016) are among the most vital factors that affect agricultural production and agriculture is dominant to India's economy and livelihood of its people (Kumar and Gautam, 2014). In India, despite recent progress in industrialization, the soundness of economy is significantly dependent upon the gross production of agricultural commodities and agriculture is the mainstay of millions of teeming population with crops pre-dominantly dependent upon natural rainfall. The southwest (SW) monsoon brings about 80% of the total precipitation over the country. Changes in the pattern, frequency and variability of SW monsoon (Sinha and Srivastava, 2000; Seo and Ummenhofer, 2017) would have a significant impact on agricultural production, water resources management and overall economy of the country (Saha and Mooley, 1979). In view of the above, a number of studies have attempted to investigate the trend of climatic variables for the country. These studies have looked at the trends on the country scale (Kumar *et al.,* 2010; Athar, 2015; Fan and Chen, 2016; Szabó *et al.,* 2019), regional scales (Bhutiyani *et al.,* 2007; Elnesr *et al.,* 2010; Karpouzos and Kavalieratau, 2010; Duhan and Pandey, 2013; Duan *et al.,* 2017), and at the individual stations (Sahu *et al.,* 2012, 2013, 2014, 2016; Beyene, 2015). In fact, local and regional scale analysis (Fischer and Ceppi, 2012; Babar and Ramesh, 2013) is more relevant to devise-specific development and adaptation plans to mitigate negative effects of climate change. This article gives an exhaustive coverage of the reported studies dealing with two variables which are critical in climatic studies: rainfall and temperature. Temperature and its changes (Smadi, 2006; Tabari and Talaee, 2011), impact a number of hydrological processes including rainfall and these processes, in turn also impact temperature. The trend analysis of rainfall (Partal and Kahya, 2006; Addisu *et al.,* 2015; Neil and Notodiputro, 2016; Singh and Srivastava, 2016) temperature (Arora *et al.,* 2005; Karanurun and Kara, 2011; Meshram *et al.,* 2018) and other climatic variables on different spatial scales will help in the construction of future climate scenarios.

Hence, the purpose of this study is to investigate the variability of the rainfall and temperature of KBK districts one of the most backward regions in the state of Odisha and India. Seasonal trend of both the parameters has been investigated on an inter-annual basis and the fluctuations has been calculated on monthly basis with major focus on monsoon season (June–September). This includes an understanding of the area's rainfall and temperature trends and variability. Understanding the uncertainties associated with rainfall and temperature patterns will provide a knowledge base for better management of agriculture, irrigation and other water-related activities in the selected area.

2 | STUDY AREA

KBK districts are economically backward districts of Odisha. Bolangir district lies between North latitudes 20°9′ and 21°4′ and East longitudes 82°41′ and 83°32′, Kalahandi district falls between 19°8′N and 20°25′N latitudes and 82°32′ E and 83°47′E longitude, whereas Koraput district's latitudinal extension is 18°13′N to 19°10′N and longitudinal extension is 82°5′E and 83°23′E (Figure 1). The climate of these districts is extreme and on an average these experience monsoon variety of climate. Summer season is intensely hot and winter is very cold. The whole year is divided into four seasons. The hot season starts from March to May followed by the South–West monsoon from June to September. October and November constitute the post-monsoon season. The cold season is from December to February. The average annual rainfall is 1,350 mm. The southwest monsoon is the principal source of rainfall in the districts. About 80% of the total rainfall is received during the period from June to September. The variation in the annual rainfall and temperature from year to year is not very large.

3 | DATASETS AND METHODOLOGY

Rainfall, maximum and minimum temperature monthly average observed station data have analyzed for three districts of KBK from 1980 to 2017 (37 years), have been collected from India Meteorological Department, Pune. Meteorological data collected for the station Bhawanipatna

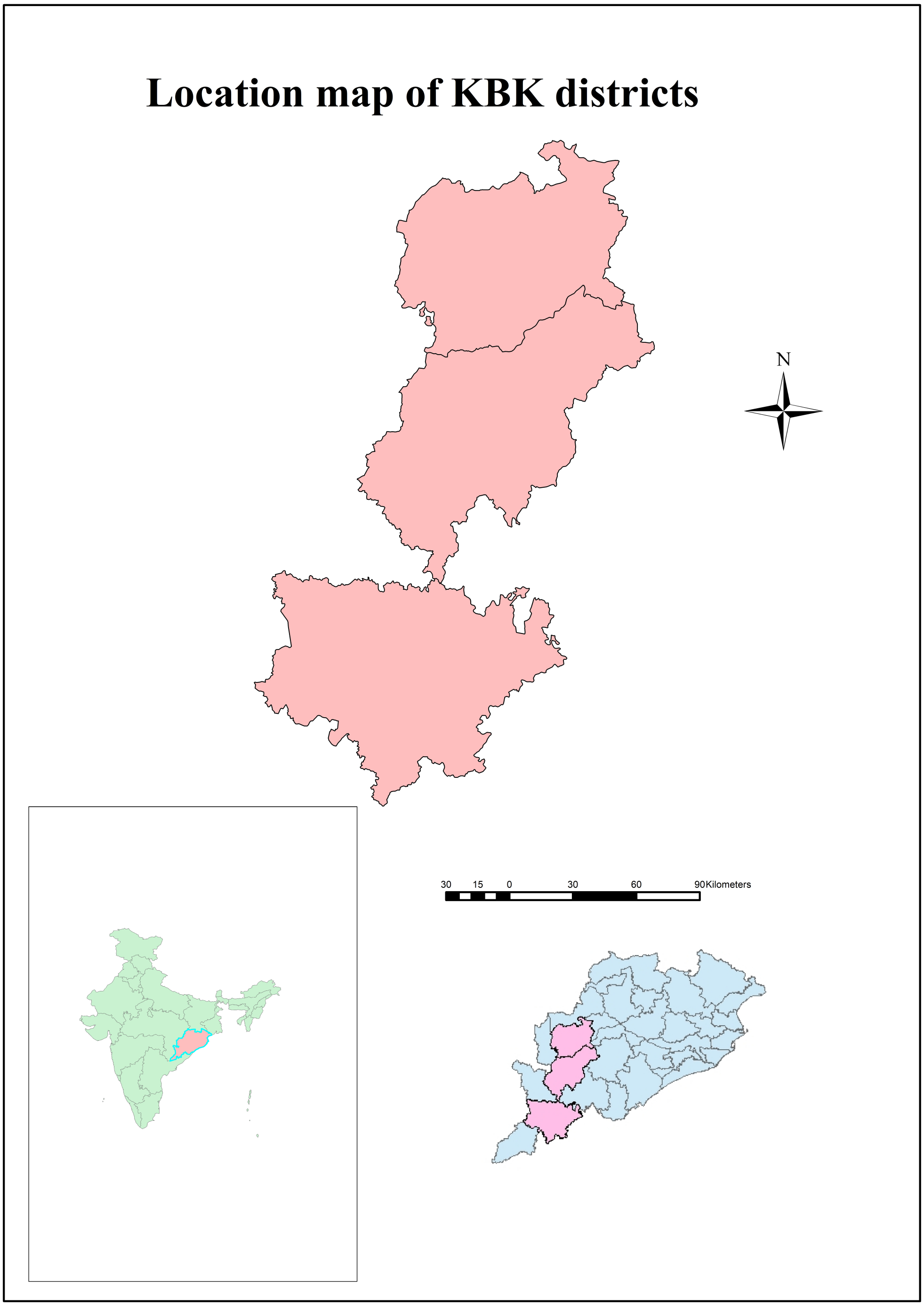


FIGURE 1 Location map of Kalahandi, Bolangir and Koraput (KBK) districts in Odisha

(Kalahandi district headquarters), Bolangir station (Bolangir district) and Koraput station (Koraput district) having IMD index no. 43,042, 42,963 and 42,097, respectively. Very few days missing values were filled in using "Imputation (most frequent)" method, which is a statistical strategy to impute missing values by replacing missing data with the most frequent values within each column.

Trend is defined as the general movement of a series over an extended period of time or it is the long-term change in the dependent variable over a long period of time (Webber and Hawkins, 1980). Trend is determined by the relationship between the two variables of temperature, rainfall and their temporal resolution. The statistical method such as regression analysis and coefficient of determination R^2 are used for the significance of trend of temperature and rainfall. The trend were derived and tested by Mann–Kendall (M–K) trend test and slope of the regression line using the least squares method. The mean, *SD* and coefficient of variation (CV) of rainfall and temperatures have been calculated to analyze the relationship.

4 | MANN–KENDALL'S TEST

The M–K test is a statistical nonparametric test widely used for trend analysis in climatological and hydrological time series data. The test was suggested by Mann (1945) and has been extensively used with environmental time series. There are two advantages to use this test. First, it is a nonparametric 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. According to this test, the null hypothesis H0 assumes that there is no trend (the data is independent and randomly ordered). This is tested against the alternative hypothesis H1, which assumes that there is trend. The M–K statistic is computed as follows:

$$S=\sum_{k=1}^{n-1}\sum_{j=k+1}^{n}\operatorname{sgn}(xj-xk)$$

The trend test is applied to a time series $X_{k,}$ which is ranked from k = 1,2,3,…,n−1, which is ranked from $j = i + 1, i + 2, i + 3\ldots.n$. Each of the data points x_j is taken as a reference point,

$$\begin{aligned}\operatorname{sgn}(xj-xk)&=1 \quad \text{if } xj-xk>0\\ &=0 \quad \text{if } xj-xk=0\\ &=-1 \quad \text{if } xj-xk<0\end{aligned}$$

This particular test has been calculated using XLSTAT 2017 software. A very high positive value of S is an indicator of an increasing trend and a very low negative value indicates a decreasing trend. The presence of a statistically significant trend is evaluated using Z value.

5 | SEN'S SLOPE ESTIMATOR TEST

The magnitude of a trend in a time series can be determined using a nonparametric method known as Sen's estimator (Sen, 1968). To estimate the true slope of an existing trend such as amount of change per year, Sen's nonparametric method is used and the test has been performed using XLSTAT 2017 software. A positive value of Sen's slope indicates an upward or increasing trend and a negative value gives a downward or decreasing trend in the time series.

6 | RESULTS AND DISCUSSION

6.1 | Results

Trend analysis in various study shows that there are generally nonparametric (Hollander and Wolfe, 1973) methods were used, M–K test (Mann, 1945Kendall, 1975) is one of the best methods among them, which is preferred by various researchers (Jain and Kumar, 2012). The descriptive statistics of rainfall such as the mean, *SD*, coefficient of variation, kurtosis and skewness are discussed in Table 1. And from the computed table, it has been found that the average monthly rainfall coefficient of variation (CV) ranging from 50.18 to 351.62%. The highest values of coefficient of kurtosis was found for the month of December that is, 9.80 and also the skewness is found to be high for December that is, 3.22. Figure 2 explains the monthly rainfall pattern, which reveals that maximum amount of rainfall occur in monsoon months that is from June to September in the study area. Figure 3 is showing the general increasing trend of seasonal rainfall in the studied region, where the linear regression equation is showing positive slope value (a = 4.104) and the R^2 value comes about 0.483. R^2 which is coefficient of determination value explains that 48% of variability in the seasonal rainfall is explained by this linear regression model.

The recorded temperature data and the employed descriptive statistics like mean, *SD*, coefficient of variation, skewness

TABLE 1 Statistical information of rainfall of Kalahandi, Bolangir and Koraput (KBK) districts

Month	Maximum	Minimum	Mean	*SD*	CV (%)	Skewness	Kurtosis
January	39.3	1.81	3.16	5.892	219.76	2.01	4.07
February	34.9	0.32	2.42	4.96	240.55	2.02	4.52
March	38.8	0.81	5.72	8.99	241.75	1.33	0.61
April	85.06	7	15.89	15.62	170.83	1.41	2.1
May	296.3	17.6	39.29	41.98	147.7	2.06	4.5
June	594.15	202	137.16	91.3	85.67	1.37	1.87
July	1,010.8	338	226.22	120.28	51.04	0.74	0.37
August	819.8	231	230.75	112.26	50.18	0.42	0.15
September	494.8	209	151.05	81.72	62.44	0.42	0.93
October	305.78	6.5	63.49	58.87	133.68	1.46	2.57
November	104.1	3.5	12.4	18.88	227.74	1.64	1.84
December	37.4	0.5	3.56	10.34	351.62	3.22	9.8

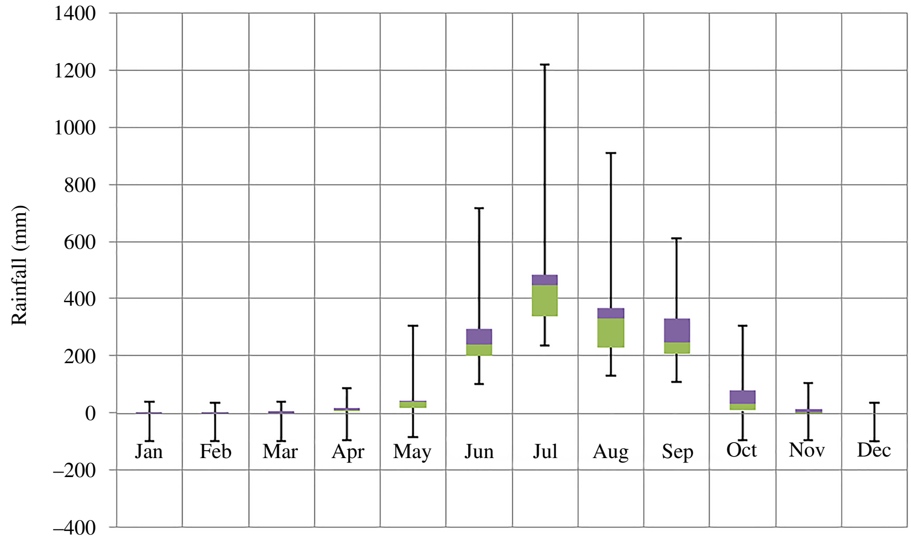


FIGURE 2 Box and whisker plot of monthly rainfall (mm) for Kalahandi, Bolangir and Koraput (KBK) districts from 1980 to 2017

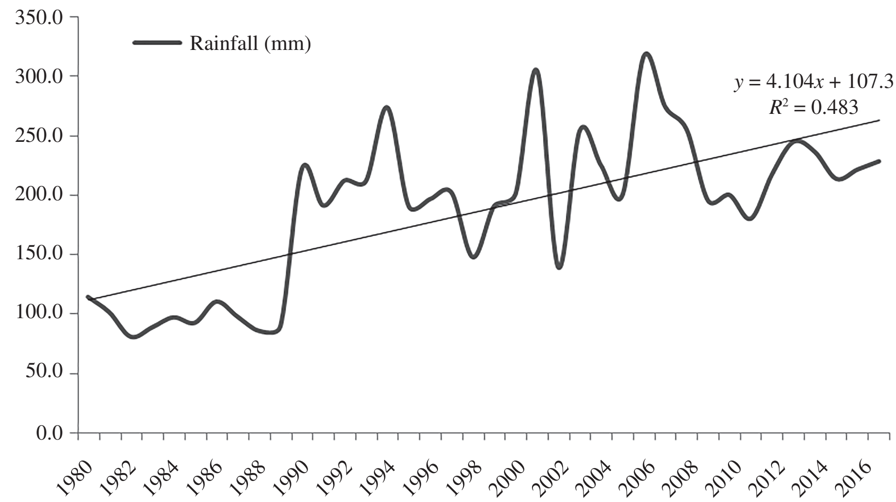


FIGURE 3 Trend of seasonal rainfall from 1980 to 2017

TABLE 2 Statistical information of maximum temperature of Kalahandi, Bolangir and Koraput (KBK) districts

Month	Maximum	Minimum	Mean	*SD*	CV (%)	Skewness	Kurtosis
January	29	18.29	27.7	2.53	9.28	−3.05	14.13
February	32.9	23.32	29.87	4.07	13.92	−3.41	13.92
March	39	31.8	34.27	3.26	9.72	−1.67	6.42
April	43	34.7	36.44	4.24	12.2	−2.16	7.04
May	42	34.2	37.76	3.52	9.7	−2.99	13.46
June	39.9	31.7	33.9	3.97	11.91	−1.94	6.97
July	35	28.1	29.44	3.28	11.57	−3.25	11.69
August	32	26.3	28.81	3.61	12.92	−2.91	9.42
September	33	29.3	29.32	5.08	17.6	−2.45	4.99
October	33.9	28.7	29.92	3.42	11.89	−2.88	9.17
November	32	14.5	28.1	3.7	13.71	−2.52	6.81
December	31.1	13.8	27.06	2.73	10.39	−2.85	12.73

Month	Maximum	Minimum	Mean	Std Dev	CV(%)	Skewness	Kurtosis
January	15.12	7.20	12.96	2.15	16.58	−1.89	5.04
February	17.28	3.94	14.91	2.95	19.73	−2.97	10.21
March	20.90	13.31	19.53	1.68	8.74	−3.57	17.7
April	24.78	15.87	22.70	2.46	11.38	−3.19	11.17
May	26.83	16.72	24.54	2.46	10.27	−2.54	10.07
June	26.09	16.18	23.77	2.45	10.51	−2.64	11.77
July	25.5	14.18	22.47	3.57	16.14	−2.49	6.04
August	24.86	13.72	22.26	3.42	15.66	−2.53	6.32
September	23.48	14.10	21.84	3.67	17.27	−2.45	6.52
October	22.05	14.16	20.10	2.54	13.00	−2.55	6.81
November	18.70	9.21	16.04	2.23	14.18	−2	6.17
December	15.91	6.43	13.11	1.81	13.82	−2.28	10.92

TABLE 3 Statistical information of minimum temperature of KBK districts

and kurtosis are given in Table 2 and 3 for maximum and minimum temperature, respectively. Although the CV for both maximum and minimum temperature is found to be low as compared to rainfall but the skewness and kurtosis values show extreme variation than rainfall. The observed data were analyzed for the period of 1980–2017 and represented through the Figures 4 and 5. From both of these figures, it become clear that the maximum and minimum temperature are low during monsoon seasons and are comparatively high during pre-monsoon months. Regarding temperature, trends found for both maximum and minimum temperature data on seasonal basis from 1980 to 2017 are not very significant. The maximum and minimum temperature trend analysis are presented in Figures 6 and 7, respectively.

M–K test is also applied for trend test, result of which is shown in Table 4. The nonparametric test, M–K method, used to analyze if there is a monotonic upward or downward trend of the variable over time, the result (Table 4) shows that there is a trend in the seasonal rainfall pattern over the studied districts. Statistically significant trends are detected for rainfall and also the result is statistically significant at 99% confidence limit during the period of 1980–2017 and here, it is noteworthy to mention that the 99% confidence limit has been decided on the basis of “z” score value. Rainfall is showing a quite good increasing trend (Sen's slope = 4.034) for JJAS season. In general, maximum temperature for the observed period showed a slight warming or increasing trend (Sen's slope = 0.29) while the minimum temperature trend showed a cooling trend (Sen's slope = −0.006) but result of maximum temperature trend analysis is statistically significant at 95% confidence limit, on the contrary the trend analysis result of minimum temperature is not statistically significant.

6.2 | Discussion

A variability analysis of meteorological parameters is of great importance for researchers and policy makers in their

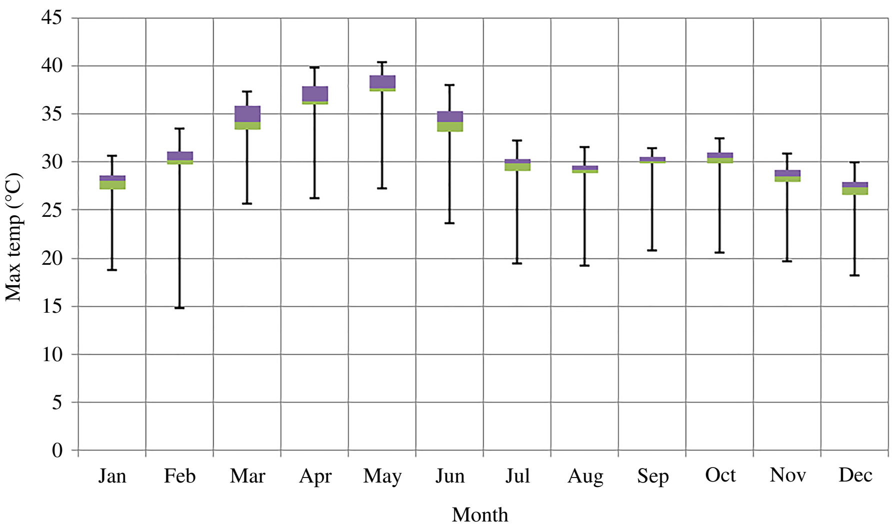


FIGURE 4 Box and whisker plot of monthly maximum temperature (°C) for Kalahandi, Bolangir and Koraput (KBK) districts from 1980–2017

FIGURE 5 Box and whisker plot of monthly minimum temperature (°C) for Kalahandi, Bolangir and Koraput (KBK) districts from 1980 to 2017

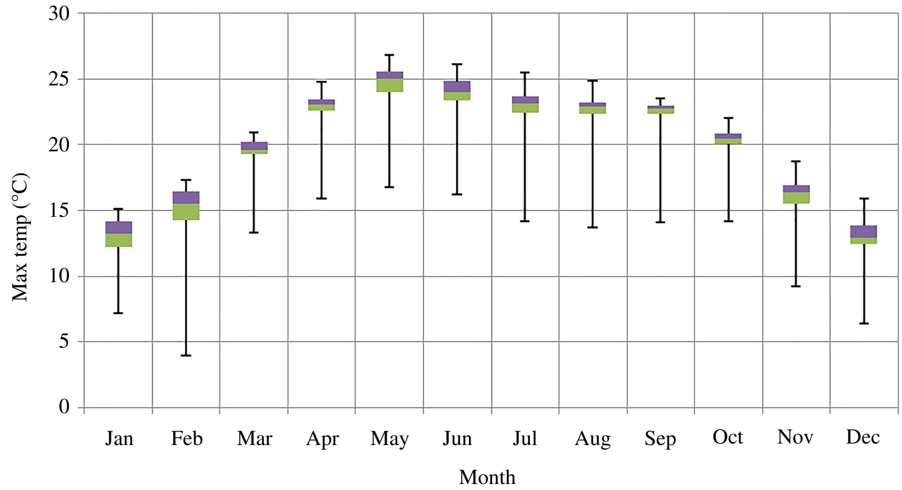


FIGURE 6 Trend of seasonal maximum temperature from 1980 to 2017

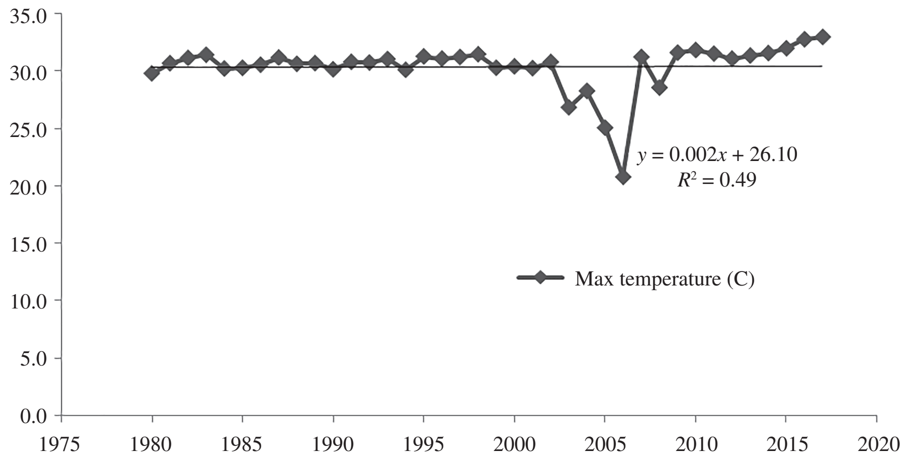
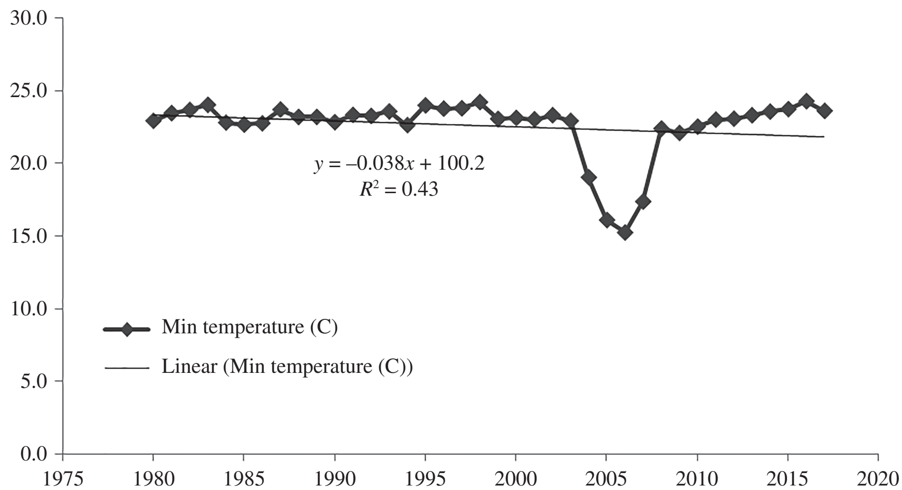


FIGURE 7 Trend of seasonal minimum temperature from 1980 to 2017



decision making as rainfall plays dominant role in deciding the use of the water availability in the areas. At the first instance, monthly rainfall variations have been shown using box and whisker plots. The compact nature of box and whisker plots (Tukey, 1977) assists side by side assessments of multiple datasets, which can otherwise be difficult to interpret using more complete representations, such as the histogram (Banacos, 2011). These plots graphically describe the statistical distribution in a way that is easy to understand for a wide range of users. The form of the box and whisker plot

TABLE 4 Mann–Kendall trend analysis

	Seasonal rainfall	Seasonal maximum temperature	Seasonal minimum temperature
Kendall's tau	0.453	0.255	−0.066
Sen's slope	4.034	0.29	−0.006
S	302	170	−44
P-value	0.001	0.027	0.274
Significance	Significant	Significant	Not significant

here include: a central horizontal line representing the median and the interquartile range's top and bottom horizontal lines (shown by the box). The bottom and top horizontal lines in the boxes indicate the 25th and 75th percentiles, respectively. The outer ranges are drawn as vertical lines (as shown by the whiskers). The location of the median line can suggest skewness in the distribution if it is noticeably shifted away from the center. The length of the interquartile range as shown by the box is a measure of the relative dispersion of the middle 50% of a dataset, just as the length of each whisker is a measure of the relative dispersion of the dataset's outer range (10th to 25th percentiles and 75th to 90th percentiles) (Banacos, 2011). Hence, it is clearly visible that the dataset are not normally distributed and most of the data fall in upper whisker that is, in the 4th quartile. According to literature, CV is used to classify the degree of variability as less (CV < 20%), moderate (20 < CV < 30%), high (CV > 30%), very high (CV > 40%) and CV > 70% indicate extremely high inter-annual variability of rainfall. Based on this, from the observed data considered that all the months had above 30% of CV highlighting the high variability of precipitation over the area. The result indicated that the amount of rainfall in the region is extremely variable. Then, if the kurtosis values are analyzed, then it can be understood that during monsoon (July, August, September) the kurtosis values are less and also the skewness value which explains that the dataset are light tailed during monsoon months and follows a symmetric pattern. In other words, we can say that rainfall in the study area follows a symmetric pattern during monsoon months. In contradiction to it, during post-monsoon as well as pre-monsoon months, the dataset show high kurtosis value, so it can be termed that rainfall during post- and pre-monsoon months follows a heavy tailed nature means the presence of outliers or extreme values are there. In the simplest form, it can be said that rainfall in the study area before and after monsoon months is asymmetrical in nature. Surface air temperature is one of the most important elements in weather and climate forecasting, so examination of its behavior is important for understanding of climate variability which can vary spatially and temporally at different local, regional and global scales (Ghasemi, 2015). In spite of the overwhelming evidence of increasing temperatures all over the world, accurate estimation of the time trends is still an open issue (Gil-Alana, 2018). In a similar way as the Air temperature has crucial impact on the water cycle in the study area, the deep understanding of the nature of its occurrence must be carried on. Unlike rainfall, the seasonal (July, August and September) maximum and minimum temperature show decreasing nature as the rainfall is at its peak during these months in the study area. And before and after monsoon months the temperature shows increasing pattern. Figure 6 represents the seasonal mean maximum temperature and its trend in the period of under examination. Using a linear regression model, the rate of change is defined by the slope of regression line which in this case is about 0.0021 °C/37 year during the period of 1980–2017. This finding is not similar to global warming rate which is estimated 0.9 ° C for the last decade. This result shows that approaching to global warming study has important impact on the regional climate in the study area for the last two decades. Also, it is observed that the average monthly maximum temperature for the studied period, the coefficient of variation (CV) varies from 9.70 to 13.92%, that means more or less the maximum temperature show stability over time and less variability is examined. The coefficient of kurtosis in case of maximum temperature is the highest in the month of January which is 14.13 and the data are negatively skewed.

The trends of seasonal mean minimum temperature over different years are also obtained using linear regression best fit lines. The linear regression trends with their linear regression equations and coefficient of determination are represented in Figure 7. The coefficient of variation for mean (Lewis and King, 2016) monthly minimum temperature shows a variation ranging from 8.74 to 19.73%. Although the variation is less, but from the study, it is proved that minimum temperature shows more variation than the maximum. As far as coefficient of kurtosis is concerned, it is the highest in June that is, 11.77 and like maximum temperature the data are negatively skewed.

7 | CONCLUSION

Odisha state is susceptible to climate variability and change and KBK districts also experience the same. Fluctuations or variations in climatic parameters is a recurring phenomena in the studied districts. The effects of climate variability exacerbate existing social and economic encounters across the area, because people here are mainly reliant on resources that are sensitive to climate variability and rainfed agriculture. Improved capacity to cope with future climate variability extremes can lessen the extent of economic, social and human loss. Rainfall and temperature are the most determinant climatic parameters in the area, as more than 80% of the agriculture is reliant on rain. The present study analyzed the meteorological data for the KBK districts in Odisha. The analysis of the time series was carried out using nonparametric M–K test and Sen's slope estimator, which are widely used tests for conducting trend analysis. The variability analysis, the monthly rainfall, maximum temperature and minimum temperature are presented using box and whisker plots. The plots show the relatively maximum amount of rainfall in monsoonal months that is, June to September, while in the case of maximum temperature and minimum temperature, the variability is more or less the same for all months when compared to the rainfall. To suggest that an underdeveloped area like KBK districts in particular is highly susceptible to the significant influences of climate variability mainly the rainfall variability and as rainfall is the main driver of agricultural growth in the studied region hence its extreme occurrence during monsoon and also during post and pre-monsoon months is very much crucial to the growth. From the analysis, it is clearly understood that both maximum and minimum temperature all over a year do not show much variability in the study region and hence agricultural productivity cannot be hampered much by temperature variability.

Therefore, the concerned stakeholders should take into consideration the rainfall variability in particular and temperature variability in general of the area into their climate change adaptation strategy.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

ORCID

Arpita Panda https://orcid.org/0000-0003-4713-1182
Netrananda Sahu https://orcid.org/0000-0001-8505-7185

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