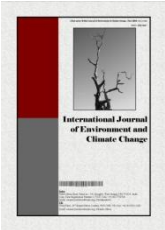

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Rainfall and Temperature Trends in Jagtial District of Telangana State

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aims: To investigate and assess the significance of the potential trend of two variables viz. rainfall, temperature in Jagtial district of Telangana state.
Place and Duration of Study: Data of Daily rainfall and temperature data of 39 years (1980-2019) collected from the meteorological observatory at Regional Agricultural Research Station, Polasa, Jagtial.
Methodology: In this study, trend analysis has been carried out on monthly, seasonal and annual basis using the data period between 1980 to 2019 for rainfall and temperature. Mann-Kendall test and Sen's slope estimate test were applied to identify the existing trend direction and magnitude of change over time.
Results: The rainfall seasonal trend analysis indicates that pre-monsoon, monsoon and post-monsoon and winter period showed a negative rainfall trend with z statistics of-1.47, -2.51, -0.55 and-1.38 respectively. However, the annual rainfall showed a negative trend with a z value of -

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2.53. In the case of Sen's slope shows that negative trend in monthly, seasonal and annual rainfall. But the significant rising trend of monthly, seasonal average temperature is noticed from 1980 onwards. The annual average maximum temperature in the Jagtial showed an increasing trend (Z value +5.03). An increasing trend in the all seasons will lead to increase in annual mean temperature. The results of minimum temperature shows a rising trend and falling trend observed Monthly. However annual mean minimum temperature in the Jagtial District showed an increasing trend (Z value 0.10). In the case of maximum temperature for the observed period, it showed rising trend (Sen's slope = 0.63) while the minimum temperature trend showed no trend (Sen's slope = 0.02).

Conclusion: Time series was carried out using nonparametric M–K test and Sen's slope estimator, which are widely used tests for conducting trend analysis. Therefore, its take into think about the rainfall variability in particular and temperature variability in general of the area into their climate change adaptation approach.

Keywords: Trend analysis; rainfall; temperature; M-K test and sen's slope.

1. INTRODUCTION

Climate is one among the key components in the earth system. There are many variables like temperature, rainfall, atmospheric pressure, humidity that constitute weather and climate. Climate is typically defined as the average weather. In wide sense, it is the statistical interpretation in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years [1]. The analysis of long-term transpose in climatic variables is a fundamental task in studies on global climate change detection. The rainfall and temperatures [2] are the foremost important fundamental physical parameters among the climate as these parameters determine the environmental condition of the particular region which influence the agricultural productivity [3, 4]. Agriculture and allied sectors, food and energy security of any region are crucially dependent on the timely availability of adequate amount of water and climate. The rainfall received in an area is an important factor in makeout the amount of water available to encounter various demands such as agricultural, industrial, domestic water supply and for hydroelectric power generation. The pattern and amount of the rainfall [5] are the most vital factors that affect agricultural production and agriculture is presiding to India's economy and livelihood of its people [4].

The southwest (SW) monsoon receives about 80% of the total precipitation over the country. Changes within the pattern, frequency and variability of SW monsoon [6, 7] would have a significant effect on agricultural production, water resources and total economy of the country [8]. In view of the above, a number of researches have attempted to investigate the trend of climatic variables for the country. These researches have glance at the trends on the country scale [9, 10,11, 12], regional scales (Duan et al., 2017; [13,14,15,16], and at the individual stations [17, 18]. In point of fact, local and regional scale analysis [19, 20] is most relate to devise-specific development and adaptation plans to mitigate negative effects of climate change.

There are numerous methods given to determine hydro-meteorological time series [13]. "Trend analysis of rainfall time series used to calculation of increasing trend and decreasing trend and magnitude of trend and its statistical significance" Jain and Kumar, [21] by utilizing parametric and non-parametric statistical methods. Trend analysis in different study shows that there are generally non-parametric methods were used, Mann-Kendall test Mann, [22] and Kendall, [23] is one among the best methods, which is preferred by many researchers [21]. "Mann- Kendall test is exercised for analysis and ascertains statistical significance by hypothesis test of hydrological variables" (Yue et al, 2003).

In view of the above, this study has been attempted to investigate the trend of climatic variables for the Jagtial district in the state of Telangana and India. There are two main variables rainfall and temperature were summarized in this article. This encompass an understanding of the area's rainfall and temperature trends and variability. Understanding the uncertainties associated with rainfall and temperature patterns will furnish a knowledge base for best management of agriculture, irrigation and other water related activities in the selected region.

2. MATERIALS AND METHODS

2.1 Study Area

Jagtial is a district of Telangana with its geographical locations 18.7895° North latitude and 78.9120° East longitude. Its elevation is 258 meter above mean sea level (Fig. 1). The climate of Jagtial district is extreme and on an average these experience monsoon variety of climate. Summer season is intensely hot and winter is cold. The whole year is divided into four seasons. The hot season begins 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 1034.5 mm. The southwest monsoon is the principal source of rainfall in Jagtial. 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.

2.2 Data Used

Daily rainfall and temperature data of 39 years (1980-2019) were collected from the meteorological observatory at Regional Agricultural Research Station, Polasa, Jagtial. These data were evaluated for trends using non-parametric Mann-Kendall test and Sen's slope estimator. Linear trends analysis was also carry through using linear regression procedure to notice the trend on monthly, seasonal and annual basis.

2.3 Trend Analysis

Trend is defined as the general movement of a series over an enlarged 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 decide 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.

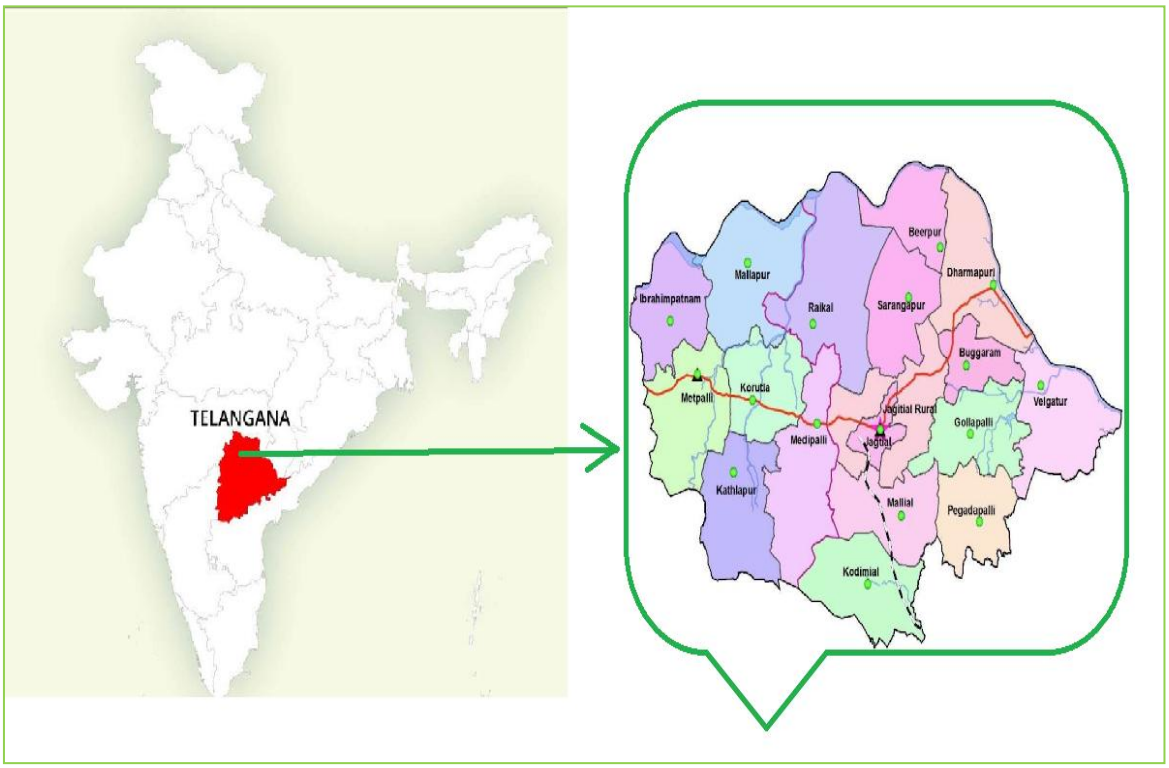

Fig. 1. Location map of Jagtial District of Telangana State

2.3.1 Mann - Kendall test

The trend analysis and estimation of Sen's slope are done using Kendall [23] and Sen's [24] method, respectively for the given data sets. Mann - Kendall test is a non-parametric test for finding trends in time series. This test compares the relative magnitudes of data rather than data values themselves [25]. The benefit of this test is that data need not to conform any particular distribution. In this test, each data value in the time series is compared with all subsequent values. Initially the Mann - Kendall statistics (S) is assumed to be zero, and if a data value in subsequent time period is higher than a data value in previous time period, S is incremented by 1 and *vice versa.* The net result of all such increments and decrements gives the final value of S. The Mann - Kendall statistics (*S*) is given as:

$$S = \sum_{J=1}^{n-1} \sum_{j=i+1}^{n} Sign\ (X_j - X_i)$$

where,

sign (*xj* - *xk*) = 1 ,
if (*xj* - *xk*) > 0; 0,
if (*xj* - *xk*) = 0; -1,
if (*xj* - *xk*) < 0.

Positive value of *S* indicates an increasing trend, and a negative value indicates a decreasing trend. However, it is necessary to perform the statistical analysis for the significance of the trend. The test procedure using the normal - approximation test is described by Kendall [23]. This test assumes that there are not many tied values within the data set. The variance (S) is calculated by the following equation:

$$Var\ (S) = {}^{1}/_{18}\ [n(n-1)(2n+5) - \sum_{P=1}^{g} t_P(t-1)(2t+5)]$$

where, *n* is the number of data points, *g* is the number of tied groups and *tp* is the number of data points in the *p*th group.

The normal *Z* - statistics is computed as:

Z = (*S*-1)/√Var(*S*), if *S*>0
Z = 0, if *S* = 0
Z = (*S*+1)/√Var(*S*), if *S*<0

The trend said to be decreasing if Z is negative and the computed Z - statistics is greater than the z - value corresponding of the 5% level of significance. The trend is said to be increasing if the Z is positive and the computed Z - statistics is greater than the z - value corresponding to the 5% level of significance. If the computed Z - statistics is less than the z - corresponding of the 5% level significance, there is no trend.

2.3.2 Sen's slope estimator

Simple liner regression is one of the most widely used model to detect the linear trend. However, this method require the assumption of normality of residuals McBean and Motiee, [26]. Vissman et al. [27] reported that many hydrological variable exhibit a marked right skewness partly due to influence of natural phenomena and do not follow a normal distribution, the Sen [24] slope estimator is found to be a powerful tool to develop the linear relationships. Sen's slope has the advantage over the regression slope in the sense that it is not much affected by gross data errors and outliers. The Sen's slope is estimated as the median of all pair - wise slopes between each pair of points is the dataset Sen, [24]. Each individual slope (*mij*) is estimated using the following equation:

mij = (*Yj* –*Yi*) / (*j* - *i*)

where,

I = 1 to *n*-1, *j* = 2 to *n*, *Yj* and *Yi* are data values at time *j* and *I* (*j* >*i*), respectively. If there are n values of Yj in the time series, there will be *N* = *n* (*n*-1)/2 slope estimates. The Sen's slope is the median slope of these *N* values of slopes.

The Sen's slope is:

m = *m* {*N*+1/2}, if *n* is odd.
m = 1/2 (*m* [*N*/2] + *m* [*N*+2/2], if *n* is even.
Positive Sen's slope indicates rising trend while negative Sen's indicating falling trend.

2.3.3 Linear regression analysis

Linear regression analysis is a parametric model and one of the most commonly used methods to detect a trend in a data series. This model develops a relationship between two variables (dependent and independent) by fitting a linier equation to the observed data. The data is first checked whether or not there is relationship between the variables of interest. This can be

done by using the scatter plot. If there appears no association between the two variables, linear regression model will not prove a useful model. A numerical measure of this association between the variables is the correlation coefficient, which range between -1 to +1. A correlation coefficient value of +1 indicates a perfect fit. A value near zero means that there is a random, nonlinear relationship between the two variables. The linear regression model is generally described by the following equation:

$Y = m X + C$

where, Y is the dependent variable, *X* is the independent variable, m is the slope of the line and C is the intercept constant. The coefficient (*m* and C) of the model are determined using the least - squares method, which is the most commonly used method. The *t*-test is used to determine whether the linear trends are significantly different from zero at the 5% significance level.

3. RESULTS AND DISCUSSION

3.1 Trend analysis of Rainfall

Trend analysis in various study shows that there are generally nonparametric (Hollander and Wolfe, 1973) methods were used, M–K test [22,23] is one of the best methods among them, which is preferred by other researchers [21]. The descriptive statistics of rainfall viz, the mean, SD, coefficient of variation, kurtosis and skewness are discussed in Table 1. Skewness is the measure of asymmetry in frequency distribution about the mean predominantly positive skewness. Kurtosis is the measure of peakedness or flatness of frequency distribution. Coefficient of variation (CV) is the compute of spread data points in data series around the mean. All the statistical parameters for Monthly, seasonal and annual rainfall basis are given in Table 1. It has been found that the average monthly, seasonal and annual rainfall coefficient of variation (CV) ranging from 34.38 to 279.15%. The highest values of coefficient of kurtosis was found for the month of January that is, 12.55 and also the skewness is found to be high for December that is, 3.46.

The results of Mann-Kendall analysis of monthly rainfall series are presented in Table 2 &7. The positive Z value refers rising trend and vice versa. It can be seen from the table that in some cases there was rising trend and in some cases rainfall is falling. The computed z-statistics is less than the z value in most cases that means that there was no significant rising or falling trend in those monthly rainfall during the period of study. The results shown in Table 2 indicated a falling trend in all months expect February with significant at 0.1 level of significance. The annual Rainfall in the Jagtial showed a Falling trend (Z value -2.53). An Falling trend in the monsoon and post-monsoon season, however, a rainfall during post-monsoon may trigger post-harvest crop losses. The magnitude of trend of monthly rainfall was calculated using Sen's slope estimator and presented in Table 2. A positive slope gives rising trend whereas negative gives falling trend. The zero slope means no trend in the rainfall series. It can be seen from the table that out of twelve month, in all months no trend was detected in monthly rainfall. Interestingly Feb month i.e winter rain is showing rising trend whereas July, August and September, i.e., monsoon rainfall showing falling trend. Out of that month of July, August which is critical monsoon month for this region for *kharif* crop point of view is showing falling trend with high magnitude. It means there need to be a planning of harvesting of June month rainfall for recycling as life saving irrigation to *kharif* crops during dry spell expected during the month of July and August. Fig. 2 depicts the Rainfall variability during the period 1980-2019. Linear regression analysis was also carried out for Annual rainfall. It also indicated the linear trend line falling on the time series for Annual rainfall from 1980-2019.

3.2 Trend analysis of Temperature

3.2.1 Maximum temperature

The preliminary data analysis was carried out to find the statistical parameters (mean, standard deviation, skewness, kurtosis and coefficient of variation) of annual maximum temperature series for the period 1980-2019. Where mean annual maximum temperature is 32.40°C with standard deviation 6.23°C. The skewness of average value -4.10 indicating annual maximum temperature in the region is asymmetric and it lies to the left of mean i.e. left skewed. Kurtosis value of 19.88 represents the platykurtic shape of annual data distribution. All the statistical parameters for annual and seasonal basis are shown in Table 3. Earlier applying the MK test all the series are tested for serial correlation using Lag^{-1} autocorrelation. The results of MK test and Sen's slope estimator are presented in Table 4&7. The results shown in Table 4 indicated a

Table 1. Descriptive statistics of rainfall

Month	Mean	Median	Standard Error	Sample Variance	Standard Deviation	Kurtosis	Skewness	Coefficient of Variance
Jan	15.00	0.00	4.81	926.00	30.43	12.55	3.18	202.87
Feb	7.31	0.10	2.06	170.29	13.05	5.35	2.30	178.46
March	10.59	0.10	2.75	303.48	17.42	1.57	1.65	164.50
April	11.48	3.30	2.89	334.21	18.28	4.50	2.17	159.27
May	18.35	4.70	5.35	1144.47	33.83	11.64	3.14	184.40
June	133.68	113.50	13.64	7446.32	86.29	0.94	0.97	64.55
July	236.25	230.45	18.55	13769.64	117.34	2.22	1.12	49.67
Aug	219.61	211.70	21.32	18178.16	134.83	3.26	1.66	61.39
Sep	154.18	119.80	15.76	9940.43	99.70	0.56	0.89	64.67
Oct	79.75	56.10	14.02	7859.97	88.66	9.03	2.53	111.17
Nov	12.95	0.70	3.47	481.16	21.94	5.30	2.23	169.35
Dec	4.26	0.00	1.88	141.41	11.89	12.16	3.46	279.15
Pre	13.47	9.10	2.36	222.07	14.90	1.86	1.57	110.62
Mon	185.93	173.08	10.50	4406.23	66.38	0.95	0.66	35.70
Post	46.35	37.30	7.10	2014.28	44.88	7.14	2.17	96.83
Winter	8.86	5.17	1.97	154.86	12.44	7.07	2.54	140.50
Annual	903.39	901.10	49.11	96482.08	310.62	0.46	0.34	34.38

rising trend in all months with significant at 0.001 level of significance. The annual average maximum temperature in the Jagtial showed an increasing trend (Z value +5.03). An increasing trend in the all seasons will lead to increase in annual mean temperature and consequently decrease the crop period. Fig. 3 depicts the annual maximum temperature variability during the period 1980-2019. It also indicated the linear trend line rising on the time series for annual maximum temperature from 1980-2019.

3.2.2 Minimum temperature

The preliminary data analysis was carried out to find the statistical parameters (mean, standard deviation, skewness, kurtosis and coefficient of variation) of annual minimum temperature series for the period 1980-2019. Minimum temperature in the Jagtial range between 13.37°C-25.02°C where mean annual minimum temperature is 19.78 0C with standard deviation 4.78°C. The predominantly negative skewness of average value -3.55 indicating annual minimum temperature in the region is asymmetric and it lies to the left of mean. Kurtosis of annual frequency distribution 14.61 indicating Platykurtic shape. All other statistical parameter for monthly, seasonal and annual rainfall basis are depicted in Table 5. In advance applying the MK test all the series are tested for serial correlation using Lag^{-1} autocorrelation. The results of MK test and Sen's slope estimator are furnished in Table 6.

Table 2. Monthly rainfall for the Mann–Kendall and Sen's Slope test (1980–2019)

	Kendall's tau	p-value	Z Value	Sen's slope
Jan	-0.0810	0.50	-0.67	0.000
Feb	0.0605	0.62	0.50	0.000
March	-0.0708	0.56	-0.59	0.000
April	-0.0786	0.49	-0.68	-0.002
May	-0.0367	0.75	-0.32	0.000
June	-0.1745	0.12	-1.57	-2.041
July	-0.20513	0.06	-1.85	-2.927
Aug	-0.1693	0.13	-1.53	-2.200
Sep	-0.0167	0.89	-0.14	-0.125
Oct	-0.0631	0.58	-0.56	-0.417
Nov	-0.0087	0.95	-0.06	0.000
Dec	-0.1908	0.13	-1.51	0.000

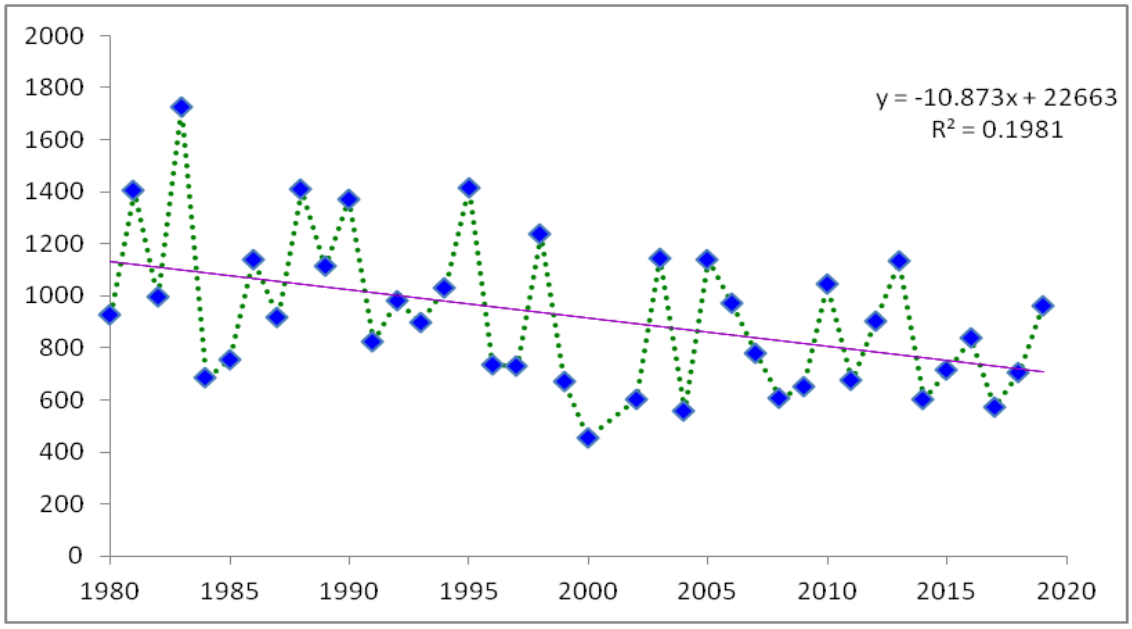

Fig. 2. Trend of Annual rainfall from 1980 to 2019

Table 3. Descriptive statistics of maximum temperature

	Mean	Median	Standard Error	Sample Variance	Standard Deviation	Kurtosis	Skewness	Coefficient of Variance
Jan	28.33	30.01	1.06	44.59	6.68	16.15	-4.10	23.57
Feb	30.46	32.19	1.15	53.31	7.30	14.91	-3.89	23.97
March	34.15	35.85	1.28	65.41	8.09	15.80	-4.03	23.68
April	37.01	39.01	1.38	75.84	8.71	16.27	-4.12	23.53
May	40.13	42.10	1.36	73.94	8.60	16.27	-4.02	21.43
June	35.15	37.25	1.32	69.98	8.37	15.43	-3.97	23.80
July	30.45	32.04	1.13	51.23	7.16	16.37	-4.13	23.50
Aug	29.89	30.62	0.80	25.60	5.06	33.23	-5.57	16.93
Sep	31.23	32.03	0.81	26.47	5.14	37.39	-6.02	16.47
Oct	31.92	32.32	0.88	30.93	5.56	29.81	-4.83	17.43
Nov	30.54	31.01	0.46	8.51	2.92	27.48	-4.84	9.55
Dec	29.50	29.25	0.20	1.52	1.23	-0.60	0.31	4.19
Pre	37.10	39.14	1.32	69.91	8.36	16.71	-4.18	22.54
Mon	31.68	33.11	0.95	36.14	6.01	22.08	-4.62	18.98
Post	31.23	31.63	0.66	17.47	4.18	30.69	-5.09	13.38
Winter	29.43	30.51	0.74	22.14	4.71	15.51	-3.98	15.99
Annual	388.77	404.68	10.82	4685.58	68.45	18.83	-4.36	17.61

Table 4. Monthly maximum temperature for the mann–kendall and Sen's Slope test (1980–2019)

	Kendall's tau	p-value	Z Value	Sen's slope
Jan	0.3492	0.00	3.16	0.054
Feb	0.3158	0.00	2.85	0.066
March	0.2157	0.05	1.95	0.045
April	0.1554	0.16	1.40	0.028
May	0.4169	0.00	3.77	0.117
June	0.2182	0.05	1.97	0.042
July	0.2619	0.02	2.37	0.044
Aug	0.4223	0.00	3.82	0.059
Sep	0.1605	0.15	1.44	0.020
Oct	0.2340	0.03	2.12	0.030
Nov	0.45828	0.00	4.1483	0.060
Dec	0.4734	0.00	4.29	0.072

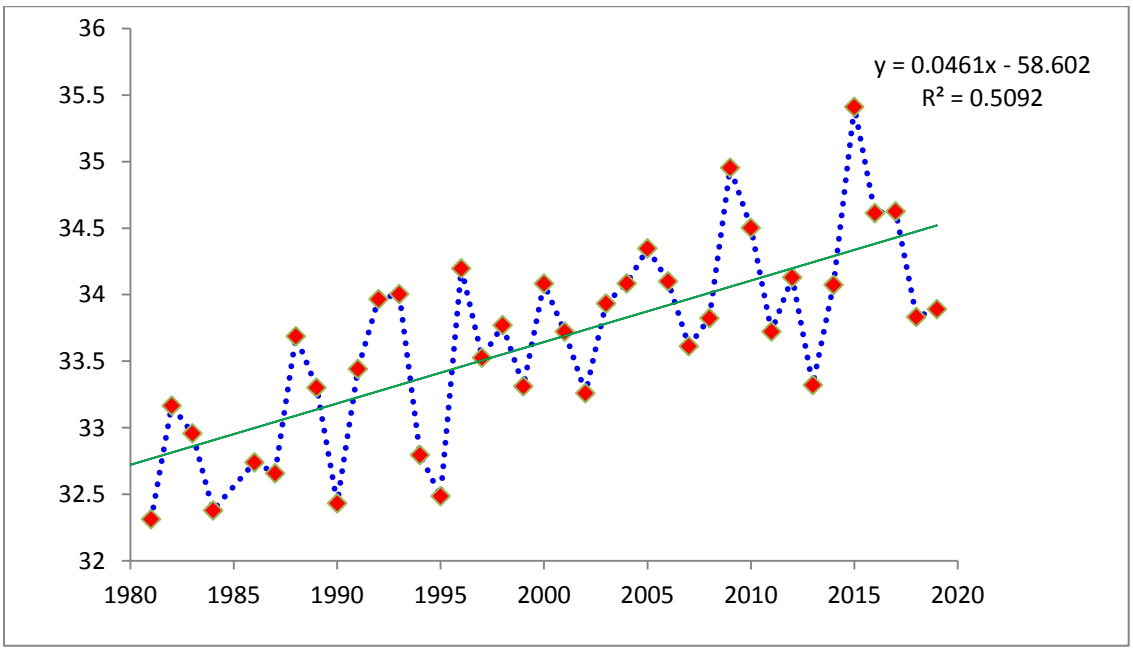

Fig. 3. Trend of annual maximum temperature from 1980 to 2019

The results shown in Table 6&7 indicated a rising trend in Feb, April, May ,July, Aug, Sep, Oct and Nov months with significant at 0.001 level of significance and falling trend observed in Jan, March, June and Dec Months. The annual mean minimum temperature in the Jagtial District showed an increasing trend (Z value 0.10). An increasing trend with highly significant minimum temperature in the monsoon and post-monsoon season will increase the duration of the summer season and enhance the global warming (Prathasarathy, B, Dhar,1974), however, a lesser significant rising minimum temperature during Pre monsoon and winter may decrease the length of crop period without reaching to its maturity hence reduce the yield. An rising in minimum temperature will support the global warming effect climate change (Kharmeshu N. 2012). This demonstrates that temperature trend shows rising and due to this rising temperature, other climatic variables may experience affected in the hydrologic processes and surrounding environment of the watershed (Rao, P.G., 1993). The minimum temperature variability during the period 1980-2019 is presented in Fig. 4.

Table 5. Descriptive statistics of minimum temperature

	Mean	Median	Standard Error	Sample Variance	Standard Deviation	Kurtosis	Skewness	Coefficient of Variance
Jan	14.39	14.65	0.43	7.26	2.69	21.41	-3.94	18.72
Feb	15.96	17.29	0.67	18.03	4.25	9.16	-2.96	26.61
March	19.03	20.16	0.73	21.06	4.59	14.47	-3.79	24.12
April	22.27	23.39	0.84	28.48	5.34	14.93	-3.87	23.96
May	25.02	26.63	1.19	56.57	7.52	7.99	-2.82	30.06
June	23.97	25.63	1.11	49.01	7.00	9.11	-3.21	29.20
July	22.62	24.16	0.86	29.82	5.46	14.41	-3.84	24.15
Aug	21.99	23.52	0.84	28.49	5.34	14.07	-3.79	24.27
Sep	22.22	23.53	0.88	31.30	5.59	12.02	-3.27	25.17
Oct	20.28	20.82	0.59	13.97	3.74	23.29	-4.25	18.43
Nov	16.20	16.63	0.49	9.45	3.07	20.04	-3.82	18.98
Dec	13.37	13.84	0.43	7.46	2.73	14.40	-3.02	20.43
Pre	22.11	23.38	0.87	30.54	5.53	12.33	-3.50	25.00
Mon	22.70	24.23	0.87	30.53	5.53	13.85	-3.74	24.34
Post	18.24	18.78	0.51	10.49	3.24	26.98	-4.75	17.76
Winter	14.57	15.19	0.43	7.42	2.72	21.66	-4.23	18.69
Annual	237.32	251.40	7.55	2278.58	47.73	16.56	-3.87	20.11

Table 6. Monthly minimum temperature for the mann–kendall and Sen's Slope test (1980–2019)

	Kendall's tau	p-value	Z Value	Sen's slope
Jan	-0.2478	0.03	-2.24	-0.045
Feb	0.0064	0.96	0.05	0.002
March	-0.0936	0.40	-0.84	-0.016
April	-0.2348	0.03	2.12	-0.047
May	0.0270	0.81	0.23	0.005
June	-0.0809	0.47	-0.72	-0.013
July	0.0475	0.67	0.42	0.005
Aug	0.1116	0.32	1.00	0.011
Sep	0.0231	0.84	0.20	0.002
Oct	0.1308	0.24	1.18	0.020
Nov	0.0731	0.51	0.65	0.017
Dec	-0.0487	0.67	-0.43	-0.012

Table 7. Seasonal and annual rainfall, Max and Min temperature for the Mann–Kendall and Sen's Slope test (1980–2019)

	Rainfall		Maximum Temperature		Minimum Temperature	
	M-K Value	Sen's slope	M-K Value	Sen's slope	M-K Value	Sen's slope
Pre	-1.47	-0.148	3.10	0.052	-1.14	-0.019
Mon	-2.51	-2.144	3.15	0.034	0.51	0.008
Post	-0.55	-0.209	2.94	0.047	1.13	0.019
Winter	-1.38	-0.083	4.92	0.069	-0.83	-0.013
Annual	-2.53	-9.989	5.03	0.63	0.10	0.02

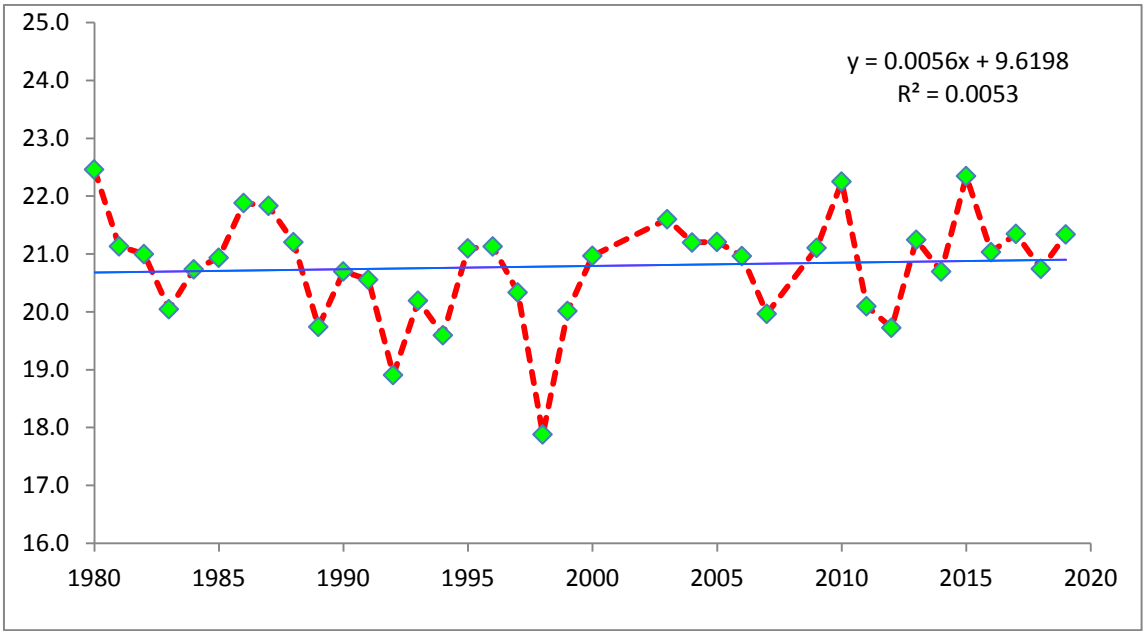

Fig 4. Trend of annual minimum temperature from 1980 to 2019

4. CONCLUSION

Northern Telangana Zone is susceptible to climate variability and change and Jagtial district also experience the same. Fluctuations or variations in climatic parameters is a recurring phenomena studied in the Jagtial district. Improved capacity to manage with future climate variability extremes can lessen the extent of economic, social and human loss. Rainfall and

temperature are the more determinant climatic parameters in the area, as more than 80% of the agriculture is reliant on rain. The paper analyzed the meteorological data for the Jagtial district in Telangana State. 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. Therefore, the concerned stakeholders should take into think about the rainfall variability in particular and temperature variability in general of the area into their climate change adaptation approach.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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