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Temperature Trends at Madhira, Khammam 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

Climate change is one of the most important global environmental challenges at global, national and regional level. The resultant global warming due to increase in temperature by 1.5°C in the near-term (2021-2040) can cause unavoidable increase in multiple climate hazards and present unknown challenges facing humanity with implications for food production, natural ecosystems, freshwater supply, health, etc. In this context, an analysis was carried out to identify trends in temperature over time series at Madhira, Khammam district in Telangana. In this trend analysis study, the annual average maximum temperature value of skewness was asymmetric and left skewed. The annual mean and maximum temperatures were significant with long-term increasing trend. In the pre monsoon season, maximum and mean temperature showed significant increase in trends in by all methods *i.e.,* M-K (Mann – Kendall), Spearman's Rho and Linear regression tests. But minimum temperature showed non-significant increasing trend. Here interestingly, monsoon season showed non-significance increase in temperature trends in all three mentioned tests. The mean of monthly maximum temperature increased at a faster rate than the average and minimum temperature. The linear regression equation indicated positive slope and R^2 was 27.0% of variability for mean annual temperature.

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1. INTRODUCTION

Temperature drives the hydrological cycle influencing the processes in a direct or indirect way. A warmer climate leads to intensification of the hydrological cycle resulting in higher rates of evaporation and increased of liquid precipitation. These processes along with shifting pattern of precipitation can affect the spatial and temporal distribution of runoff, soil moisture, groundwater reserves and increase the frequency of droughts and floods. The future climatic change, though will have itsimpact globally but will be felt severely in developing countries with agrarianeconomies like India.

Kumar et al. [1] have shown that the countrywide mean maximum temperature increased by 0.6°C during 1901 to 1987and concluded that most of the increase in means surface air temperature over India was due to the increase in daytime temperature. Ray and De [2] have summarized the existing information on climate change and trends in the occurrence of extreme events over India. The extreme maximum and minimumtemperatures showed an increasing trend in the south and adecreasing trend in the north of India. Kothawale [3] examined the extreme temperature variations in India forthe period 1970-2002 and observed that the number of hotdays was maximum over central parts and minimum alongwest coast of India during the summer months.

Global warming reaching to 1.5°C in the near-term (2021-2040) can cause unavoidable increase in unprecedented climate hazards and present numerous risks to ecosystems and humans. The level of risk will depend on concurrent nearterm trends in vulnerability, exposure, level of socioeconomic development and adaptation. The near-term actions that limit global warming close to 1.5°C would substantially reduce projected losses and damages related to climate change on human systems and ecosystems compared to higher warming levels but cannot eliminate them completely [4].

Surface air temperature isone of the most important elements in weather and climate forecasting, understanding of its behavior can be important foranalysingthe climate variability which can vary spatially and temporally at different local, regional and global scales [5]. In spite of the overwhelming evidence of increasing temperatures all over the world, accurate estimation of the time trends is still an open issue [6]. As the air temperature has crucial impact on the water cycle in the study area, for deep understanding of the nature of its occurrence at micro scale level temperature trend was carried out. The main objective of this paper is to analyze the variability and trend in temperature of Madhira, Khammam district of Telangana from 2005-2021.

2. MATERIALS AND METHODOLOGY

2.1 Data

The data was collected from the agrometeorological observatory present at Agriculture Research Station (ARS), Madhira lying between 16.9182°N latitude, 80.3633°E longitude can be Khammam district of Telangana state. The state, in general, experiences tropical climate and is geographically located in a semi-arid area and has predominantly hot and dry climate. The average elevation of the plateau area is about 500 metres. Khammam district lies in the central Telangana and receives an annual rainfall (June to May) from 800 to 1300 mm. Minimum and maximum temperatures during winter and summer ranges between 18°C- 25°C and 32°C-38°C, respectively. Red soils are predominant which includes chalks, red sands and deep red loams along with very deep black cotton soils. Important crops grown in this zone are Cotton, Rice, Maize, Greengram, Mango and Chilies etc. The soil and mean air temperature data was collected from Agrometeorological Automatic Weather Station, Krishi Vigyan Kendra, Wyra, Khammam district.

The temperature data was analyzed for monthly, seasonal and annual from 2005 to 2021 for 17 years by using different types of statistical tools. The whole year was divided into four seasons by following India Meteorological Department, New Delhi norms. The winter season starts from December to February followed by summer season from March to May. Southwest monsoon starts from June to September followed by post monsoon of October and November.

2.2 Methodology

Trend is the general movement of a series over an extended period of time or it is the long-term change on the dependent variable over a long period of time [7]. Trend can be determined by the relationship between the surface air temperature and its temporal resolution. The statistical methods like regression analysis and coefficient of determination R^2were used for deducing significance of temperature trends. The trend analysis was derived and tested by Mann-Kendall (non-parametric) trend test, Spearman's Rho (non-parametric) and Linear regression (parametric).

The non-parametric of Mann-Kendall (M-K) test was suggested by Mann [8] and extensively used for environmental time series. It is a non-parametric test and does not require the data to be normally distributed has low sensitivity to abrupt breaks due to inhomogeneous time series. According to this test, the null hypothesis H_0 assumes that there was no trend (the data is independent and randomly ordered). It can be tested against the alternative hypothesis H_1, which assumed that there was trend. The M–K statistic and was computed as follows:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn\,(x_j - x_k)$$

The trend test is applied to a time series x_k, ranked from k = 1,2,3…, n−1, and j = i+ 1, i + 2, i + 3…. n. Each of the data point's x_j was taken as a reference point,

$sgn\,(x_j - x_k) = 1$if $x_j - x_j > 0$
=0 if $x_j - x_j = 0$
= −1 if $x_j - x_j < 0$

A very high positive value of S is an indicator of an increasing trend and a very low negative value indicated a decreasing trend. The presence of a statistically significant trend was evaluated using Z value.

Spearman's rho [9] and [10] test is another rank-based non-parametric method used for trend analysis and applied as a comparison with the Mann-Kendall test. The test assumes that time series data were independent and identically distributed, the null hypothesis (H_0) again indicated no trend over time, the alternate hypothesis (H_1) was that a trend existed and that data increased or decreased. The positive values represented an increasing trend over the time series and negative values represented the decreasing trends.

Spearman rank correlation coefficient (ρ) = $S_{xy} \big/ (S_x S_y)^{0.5}$

Where, $Sx = \sum_{i=1}^{n} (x_i - \bar{x})^2$

$$Sy = \sum_{i=1}^{n} (y_i - \bar{y})^2$$

$$Sxy = \sum_{i=1}^{n} ((x_i - \bar{x})(y_i - \bar{y})$$

x_i (time), y_i(variable of interest), $\bar{x}$ and$\bar{y}$ refer to the ranks.

The parametric test, linear regressionis assumed data to be normally distributed and examined whether there was a linear trendbetween time (x) and the variable of interest (y).The regression gradient was estimated by,

$$b = \frac{\sum_{i=1}^{n} ((x_i - \bar{x})((y_i - \bar{y})}{\sum_{i=1}^{n} (x_i - \bar{x})^2}$$

and the intercept was estimated as $a = \bar{y} - bx$, the test statistic S is

S = b / σ

Where, $\sigma = \sqrt{\frac{12 \sum_{i=1}^{n} (y_i - a - bx_i)}{n(n-2)(n^2-1)}}$

The test statistic S follows a Student-tdistribution with n-2 degrees of freedom. The linear regression test assumed that the data was normally distributed. The trend wasdeterminedby Trend/change detection software [11].

3. RESULTS AND DISCUSSION

3.1 Maximum Temperature

The descriptive data analysis of statistical parameters (mean, median, standard deviation, skewness, kurtosis and coefficient of variation) of maximum temperature was carried out for the period 2005-2021. In this analysis, mean annual maximum temperature was 34.2±1.08°C.Kurtosis value was3.05 which was the nearer to medium peak shape indicating slightly above normal distribution. The average value of the skewness was -1.76 indicating annual maximum temperature in the region was asymmetric and was left skewed. All the statistical parameters for monthly, seasonal and annual basis were shown in Table 1.The spatial distribution of annualmean temperature showed a range of 31.5 to 34.6°C across various locations of the state. Highest annual temperaturesof 35.0°Cat Khammam followed by 34.9°C at BhadradriKothagudem district and 34.8°C at Suryapet [12].

3.2 Minimum Temperature

The descriptive data analysis of statistical parameters (mean, median, standard deviation, skewness, kurtosis and coefficient of variation) forminimum temperature was carried during2005-2021. In this analysis, mean annual minimum temperature was 22.6 °C ± 2.62 °C. Kurtosis value was-0.98overall resembled light tailed to platykurtic distribution. The average value of the skewness was0.34 indicating annual minimum temperature in the region was symmetric and wasright skewed. All the statistical parameters for monthly, seasonal and annual basis were shown in Table 2. The state as a whole experienced a minimum temperature of 21.8°C on an annual basis. However, thereare differences in the districts. The annual higher minimum temperatures of 25.8°Cover Khammam, 25.6°C atSuryapet,25.5°C at Wanaparthy, Hyderabad and Bhadradri Kothagudem where observed [12].

3.3 Average Temperature

The descriptive data analysis of statistical parameters of average temperatures were carried out and mean annual minimum temperature was 28.3± 1.56°C. Kurtosis value was-1.28overall resembled light tailed *i.e.,* platykurtic distribution. The average value of the skewness was0.31 indicating annual minimum temperature in the region was symmetric and was right skewed. All the statistical parameters for monthly, seasonal and annual basis were shown in Table 3.

The annual mean temperature (29.1°C) has shown slight increasing trend with highest mean temperature in 2015-16for Khammam district [12].

3.4 Trend Analysis of Temperature

The trends of seasonal maximum, minimum and mean temperatures over different years were obtained using linear regression best fit lines.

3.4.1 Annual temperature trends

The annual mean and maximum temperatures showed significant long-term increasing trend and presented in Table 4. The M-K and Spearman's Rho tests showed significance level at 0.01 % whereas, linear regression showed significance level at 0.05%for annual mean temperature. The M-K test minimum temperature was significantly increased at 0.1 levels. The annual T_{mean}, T_{max} and T_{min} along with trend line showed increasing trend and presented in Fig. 1. The linear regression equation indicated positive slope value (b = 0.160) and R^2 was 27.0 % of variability in mean annual temperature.

The trend analysis showed that there was increasing trend in minimum, maximum and mean temperatures due to global warming or climate change affecting crop production during crop-growing periods due to increased the crop evapotranspiration [13,14]. The mean maximum temperature series showed a rising trend at most stations mean of minimum temperatures showed rising at stations in south, central and western parts of India [15].

3.4.2 Winter temperature trends

During winter season there was significant increase in the maximum and mean temperatures in all three tests at 0.01 levels as shown in Table 5. The winter minimum temperature showed significantly increasing trend at 0.01 levels in Spearman's Rho (non-parametric).The winter T_{mean}, T_{max} and T_{min} along with trend line showed increasing trend and presented in Fig. 1. The linear regression equation showed positive slope value b = 0.173 and R^2was25.8% of variability in mean annual temperature. Similar results were reported by Kharbade et al. [16] during winter season in Pune region with no significant increase in the maximum and minimum temperatures.

3.4.3 Pre monsoon temperature trends

In the pre monsoon season, maximum and mean temperature showed significant increase in trends at 0.01 and 0.05 levels in all three methods whereas minimum temperature showed non-significance for increasing trend. The T_{mean}, T_{max} and T_{min} of pre monsoon temperature trend showed slightly increasing trends as shown in Fig. 2. A positive slope value of b was 0.222 and 43.8 %of R^2 variability was found for maximum temperature trends of linear regression equation. Arora et al. [17] analyzed a series of annual and seasonal mean temperature, annual mean maximum temperature and annual mean minimum temperature for many stations throughout the country with south, central and western parts of India showed a rising trend where the northern parts showed decreasing trend.

Table 1. Monthly and seasonal maximum temperatures mean, median, SD, CV, Kurtosis and Skewness

Year	Mean (°C)	Median(°C)	Standard Error	Standard Deviation	Coefficient of Variation	Kurtosis	Skewness
Jan	30.8	30.7	0.64	1.68	5.44	6.23	-1.62
Feb	33.5	33.6	0.74	1.82	5.42	6.75	-1.82
March	36.3	36.6	0.76	1.71	4.70	8.82	-2.68
April	39.0	39.6	0.92	2.27	5.82	7.60	-2.44
May	41.2	41.4	0.61	1.84	4.47	4.48	-1.76
June	37.5	37.6	0.59	2.43	6.50	-0.75	-0.43
July	33.3	33.4	0.38	1.55	4.66	0.13	0.03
Aug	33.0	33.0	0.29	1.19	3.62	-0.28	0.08
Sept	33.1	33.2	0.36	1.48	4.47	2.29	-1.27
Oct	32.4	33.2	0.47	1.96	6.04	-0.07	-0.88
Nov	30.9	31.4	0.55	2.28	7.37	3.41	-1.72
Dec	30.0	30.5	0.48	2.00	6.66	8.46	-2.62
Winter	32.2	32.1	0.68	1.68	5.22	7.08	-1.81
Pre monsoon	38.8	39.0	0.72	1.70	4.37	9.21	-2.71
Southwest	34.2	34.6	0.33	1.35	3.93	1.06	-1.06
Northeast	31.1	31.4	0.47	1.92	6.19	4.87	-2.03
Annual	34.2	34.5	0.35	1.08	3.17	3.05	-1.76

Table 2. Monthly and seasonal minimum temperatures mean, median, SD, CV, Kurtosis and Skewness

Year	Mean °C	Median °C	Standard Error	Standard Deviation	Coefficient of Variation	Kurtosis	Skewness
Jan	18.4	17.8	1.00	4.11	22.39	5.30	1.71
Feb	20.8	20.0	1.22	5.04	24.19	2.84	1.39
March	22.9	21.6	1.05	4.33	18.88	2.17	1.43
April	25.4	24.0	1.08	4.45	17.53	4.52	1.86
May	26.1	25.3	0.74	3.05	11.67	-0.50	0.30
June	24.6	24.0	0.57	2.35	9.55	0.76	1.12
July	23.6	23.3	0.57	2.35	9.96	0.19	0.73
Aug	23.4	23.6	0.51	2.10	8.97	-0.61	0.22
Sept	23.7	23.3	0.57	2.35	9.95	-0.82	0.36
Oct	22.6	21.5	0.57	2.34	10.36	-0.89	0.54
Nov	21.0	19.9	0.94	3.89	18.52	0.96	0.84
Dec	18.6	17.7	1.18	4.85	26.10	0.62	0.91
Winter	19.6	18.9	1.08	4.44	22.65	4.61	1.64
Pre monsoon	24.8	23.9	0.92	3.80	15.31	2.42	1.39
Southwest	23.8	23.9	0.49	2.02	8.46	-0.52	0.35
Northeast	20.7	20.5	0.82	3.37	16.26	-0.53	0.53
Annual	22.6	21.5	0.63	2.62	11.59	-0.98	0.34

Table 3. Monthly and seasonal average temperatures mean, median, SD, CV, Kurtosis and Skewness

Year	Mean (°C)	Median (°C)	Standard Error	Standard Deviation	Coefficient of Variation	Kurtosis	Skewness
Jan	24.4	23.9	0.68	2.82	11.58	6.01	1.89
Feb	26.9	26.2	0.84	3.46	12.85	3.15	1.44
March	29.4	28.5	0.73	3.00	10.21	1.32	0.61
April	31.9	31.4	0.79	3.25	10.18	1.42	0.67
May	33.5	33.4	0.49	2.00	5.97	-0.55	-0.02
June	31.0	30.6	0.47	1.95	6.29	0.20	0.89
July	28.5	28.3	0.43	1.77	6.23	0.57	0.88
Aug	28.2	27.8	0.33	1.35	4.80	-0.66	0.17
Sept	28.4	28.4	0.36	1.49	5.24	-0.53	-0.18
Oct	27.5	27.4	0.37	1.53	5.58	-0.26	-0.63
Nov	26.0	25.9	0.60	2.46	9.47	-0.04	-0.11
Dec	24.3	23.5	0.67	2.74	11.30	-0.19	0.65
Winter	25.7	25.0	0.74	3.07	11.94	5.06	1.71
Pre monsoon	31.6	31.1	0.64	2.63	8.32	0.97	0.60
Southwest	29.0	28.8	0.34	1.41	4.85	-0.46	0.23
Northeast	25.9	26.0	0.51	2.10	8.09	-0.62	-0.01
Annual	28.3	28.1	0.38	1.56	5.49	-1.28	0.31

Table 4. Annual temperature trend analysis

Temperature	Mann- Kendall (Non parametric)	Spearman's Rho (Non parametric)	Linear regression (Parametric)
Maximum	2.760***	2.833***	4.066***
Minimum	1.483*	1.039	1.332
Mean	2.389***	2.069***	2.365**

*Note: *** = significant at 0.01, ** = significant at 0.05, * = significant at 0.1 level*

Table 5. Winter temperature trend analysis

Temperature	Mann- Kendall (Non parametric)	Spearman's Rho (Non parametric)	Linear regression (Parametric)
Maximum	2.678***	2.824***	2.761**
Minimum	1.236	1.559*	1.1
Mean	2.142***	2.029**	2.288**

*Note: *** = significant at 0.01, ** = significant at 0.05, * = significant at 0.1 level*

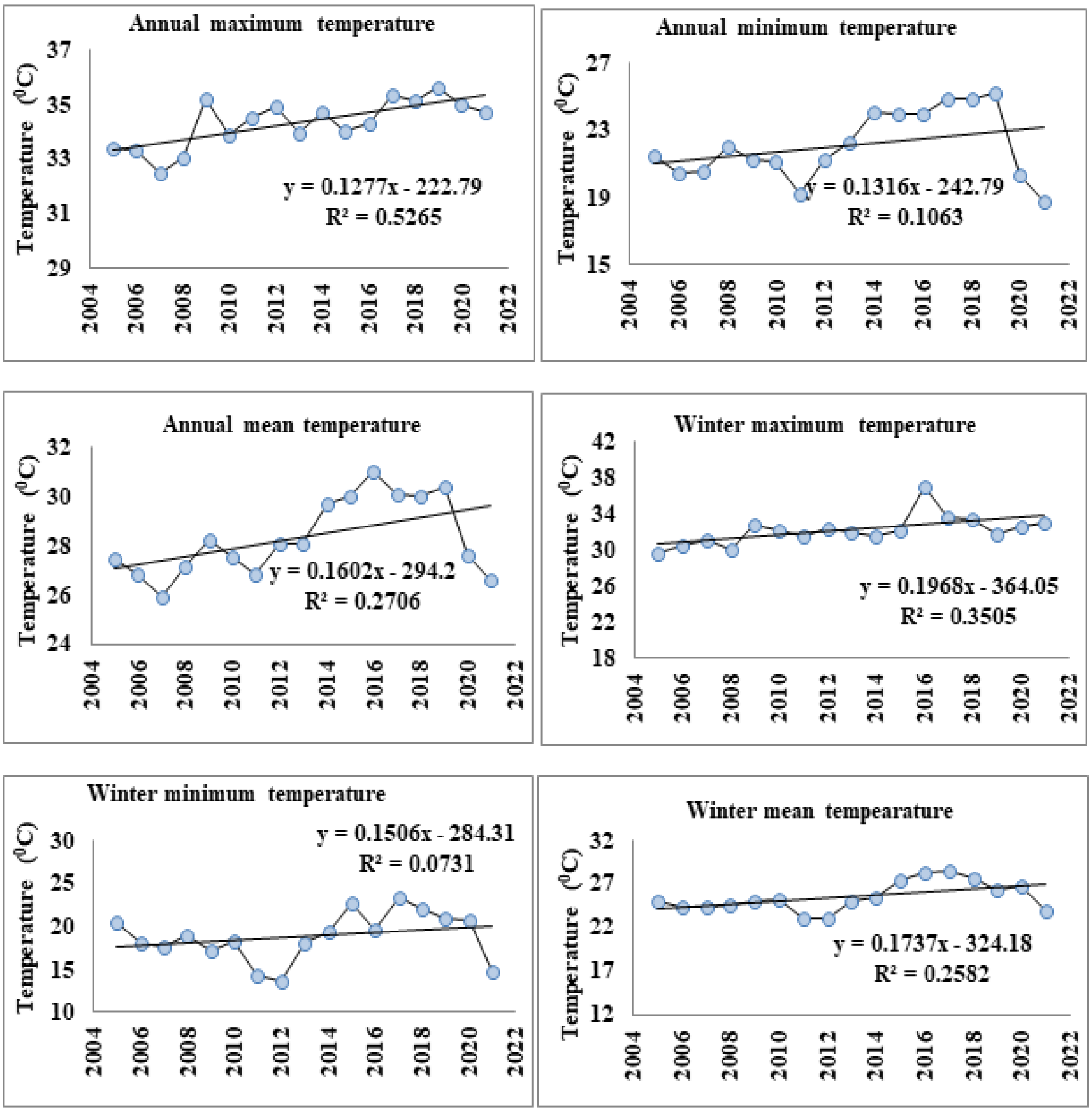

Fig. 1. Annual and winter temperature trends at Madhira between 2004-2021

Table 6. Pre monsoon temperature trend analysis

Temperature	Mann- Kendall (Non parametric)	Spearman's Rho (Non parametric)	Linear regression (Parametric)
Maximum	2.595***	2.667***	3.488***
Minimum	1.071	0.922	1.282
Mean	2.183***	1.853**	2.384**

*Note: *** = significant at 0.01, ** = significant at 0.05, * = significant at 0.1 level*

3.4.4 Monsoon / southwest monsoon temperature trends

Interestingly, monsoon season showed non-significance increase in temperature trends at Madhira for all three tests as presented in Table 7 and Fig. 2. There was slightly increase in temperature trends with a positive slope value (b = 0.040) and 2.60 %of R^2 variability maximum temperature trends of linear regression equation. Pant and Kumar [18] analyzed seasonal and annual air temperature series for South Asia and found that the monsoon temperature did not show a significant trend in most parts of the country, except for a significant negative trend over northwest India.

Table 7. Southwest monsoon temperature trend analysis in India

Temperature	Mann- Kendall (Non parametric)	Spearman's Rho (Non parametric)	Linear regression (Parametric)
Maximum	1.316	1.316	1.753
Minimum	0.947	0.882	0.721
Mean	0.494	0.529	0.625

*Note: *** = significant at 0.01, ** = significant at 0.05, * = significant at 0.1 level*

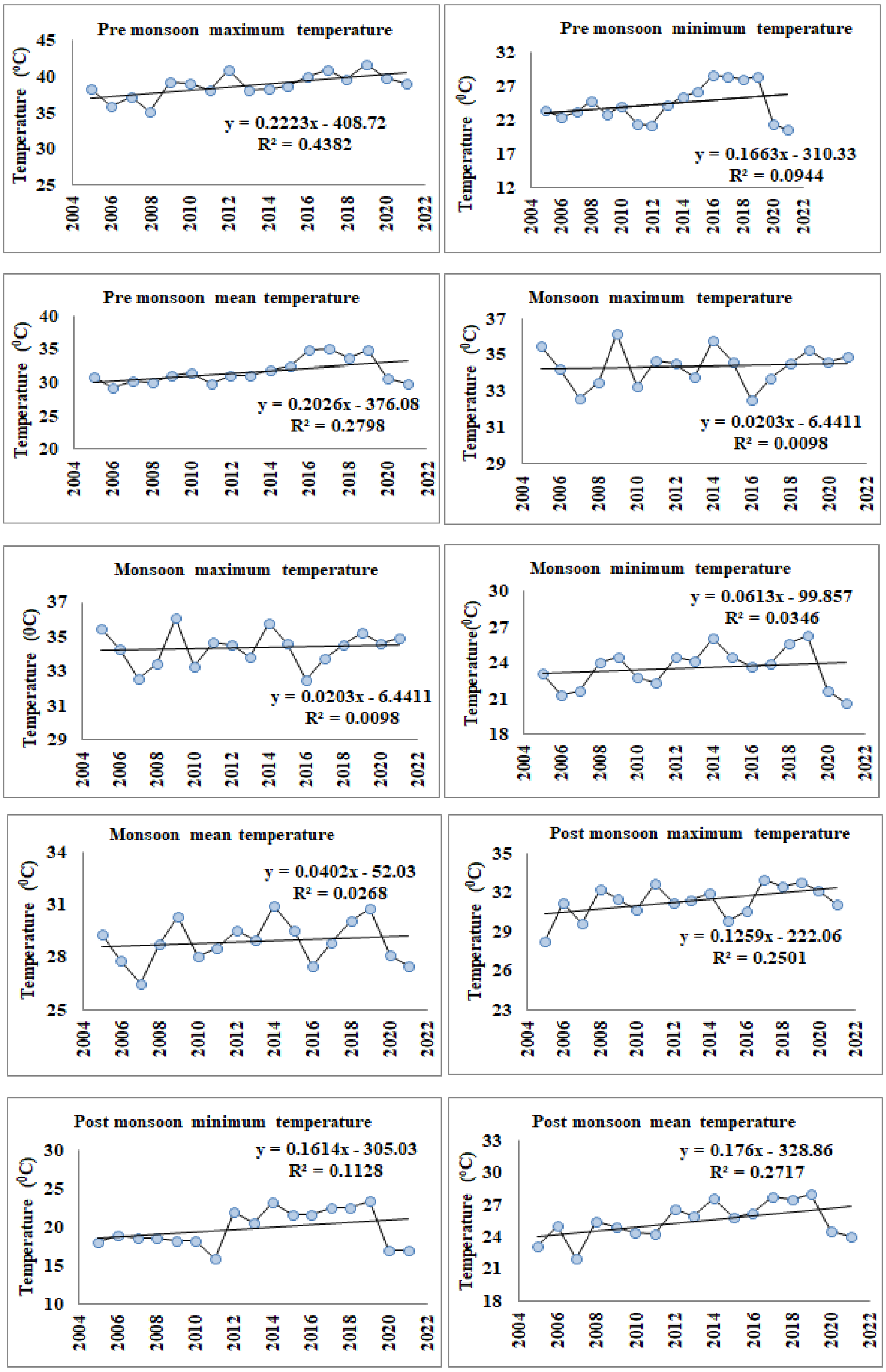

Fig. 2. Pre monsoon, monsoon and winter temperature trends at Madhira from 2004-2021

Table 8. Post monsoon temperature trend analysis

Temperature	Mann- Kendall (Non parametric)	Spearman's Rho (Non parametric)	Linear regression (Parametric)
Maximum	0.618	0.696	0.431
Minimum	1.401	1.127	1.385
Mean	1.936	1.824	2.428

*Note: *** = significant at 0.01, ** = significant at 0.05, * = significant at 0.1 level*

Table 9. Monthly temperature trends

Month	Maximum temperature			Minimum temperature			Mean temperature		
	Mann-Kendall	Spearman's Rho	Linear regression	Mann-Kendall	Spearman's Rho	Linear regression	Mann-Kendall	Spearman's Rho	Linear regression
Jan	1.565*	1.304	1.271	1.565*	1.304	1.271	2.183***	2.451***	2.609**
Feb	2.595***	2.824***	2.699**	0.824	0.961	0.837	1.318*	1.549*	1.743
March	2.307***	2.461***	3.221***	0.165	0.333	0.946	1.153	1.422*	2.014*
April	2.307***	2.461***	2.394**	1.195	0.833	1.119	2.224*	2.059**	2.284**
May	-0.041	-0.225	-0.099	1.607**	1.598**	1.803*	2.636***	2.314***	2.553**
June	0.618	0.716	0.706	0.741	0.863	1.084	0.618	0.716	0.706
July	-0.041	-0.225	-0.099	0.577	0.480	0.377	0.247	0.137	0.179
Aug	-0.206	-0.137	-0.281	0.618	0.696	0.473	0.001	0.108	0.243
Sept	0.989	1.118	0.847	0.494	0.520	0.632	0.824	1.039	0.932
Oct	0.824	1.333	1.299	1.277	1.529*	1.568	1.812**	1.784**	2.051*
Nov	2.719	2.539	2.982	2.183**	1.52*	1.652	2.760***	2.294***	2.85**
Dec	1.112	1.245	1.637	0.700	0.735	0.850	1.730**	1.431*	1.602

*Note: *** = significant at 0.01, ** = significant at 0.05, * = significant at 0.1 level*

Table 10. Correlations coefficients of soil temperature at different levels of depth under climate change conditions at KVK, Wyra, Khammam district during 2021-22

Parameters	Correlation coefficient(r) 10 cm depth	Correlation coefficient(r) 30 cm depth	Correlation coefficient(r) 70 cm depth	Correlation coefficient(r) 100 cm depth
Monsoon	0.8079	0.6788	0.4685	0.3706
Post monsoon	0.7705	0.7068	0.5503	0.2879
Winter	0.5583	0.4824	0.3157	0.2502
Pre monsoon	0.8546	0.8664	0.8732	0.8789
Annual	0.5693	0.5289	0.4271	0.3745

3.4.5 Post monsoon temperature trends

The period of post monsoon temperatures showed non-significant increase in trends for all trend tests (Table 8). The Fig. 2 showed an increase in temperature trends. A positive slope value (b = 0.176) and 27.1 % of R^2 variability was found for maximum temperature trends of linear regression equation. The magnitude of warming was higher in the post-monsoon and winter seasons in India [17].

3.4.6 Monthly temperature trends at Madhira

Trends of minimum, maximum and mean temperature were studied for individual months using M-K test, Spearman's Rho test and Linear regression tests and results presented in Table 9. Maximum and mean temperatures showed significant increase in trend from of January to May. The mean temperature was again significantly increasing from October to December during the study period. The minimum temperature showed significant increasing trend for the months of May, October and November. The mean of monthly maximum temperature increased at a faster rate than the average temperature and minimum temperature in Bhubaneswar during 1970-2015 [19]. Most of the studies of monthly minimum temperature showed a rising and falling trend throughout India. However, annual mean of minimum temperature showed an increasing trend at Jagtial district of Telangana during 1989 to 2019 [20].

3.5 Soil Temperature

The correlation between mean air temperature and soil temperature were presented in the Table 10. The Pearson's correlation coefficient results showed that positive non-significant increase trend in all climatic seasons and annual basis.

4. CONCLUSION

In trend analysis studies, the annual average maximum temperature value of the skewness was asymmetric and was left skewed whereas average annual minimum temperature value of the skewness was symmetric and right skewed. The annual mean and maximum temperatures were significant with long-term increasing trend. In the pre monsoon season, maximum and mean temperature showed significant increase in trends in all three methods *i.e.,* M-K, Spearman's Rho and Linear regression tests. But minimum temperature showed non-significant increasing trend for mean annual temperature. Here interestingly, monsoon season showed non-significance increase in temperature trend in all three tests. The mean of monthly maximum temperature increased at a faster rate than the average and minimum temperature. The linear regression equation indicated positive slope and R^2 was 27.0 % of variability for mean annual temperature. Therefore, the concerned stakeholders that include farmers, agricultural scientists and others should take consideration of increase in temperature for climate change adaptation approach practices to minimize crop and monitory loss to the farmers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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