Environment Conservation Journal 24 (2):132-141, 2023

Journal homepage:https://www.environcj.in/

Environment Conservation Journal

ISSN 0972-3099 (Print) 2278-5124 (Online)

Micro scale level rainfall trend analysis at Madhira, Khammam district of Telangana

Nagaraju Dharavath ✉
Krishi Vigyan Kendra, Professor Jayashankar Telangana State Agricultural University , Wyra, Khammam, India.
Juvva Hemantha Kumar
KrishiVigyanKendra, Professor Jayashankar Telangana State Agricultural University , Wyra, Khammam, India.
Katroju Ravi Kumar
KrishiVigyanKendra, Professor Jayashankar Telangana State Agricultural University , Wyra, Khammam, India.
Jessie Suneetha Wesley
KrishiVigyanKendra, Professor Jayashankar Telangana State Agricultural University , Wyra, Khammam, India.
Kasani Rukmini Devi
Agriculture Research Station, Madhira, India.
Vanam Chaithanya
KrishiVigyanKendra, Professor Jayashankar Telangana State Agricultural University , Wyra, Khammam, India.
P. S. M. Phanisri
KrishiVigyanKendra, Professor Jayashankar Telangana State Agricultural University , Wyra, Khammam, India.
Ravula Uma Reddy
RARS, Professor Jayashankar Telangana State Agricultural University, Warangal, India.
J. V. Prasad
ICAR-ATARI, Santhosh Nagar, Hyderabad, India.
A. Sravani
Met Centre Hyderabad, India.

ARTICLE INFO

Received : 15 July 2022
Revised : 27 October 2022
Accepted : 14 November 2022

Available online: 08 March 2023

Key Words:
Decadal rainfall
Madhira
Monsoon season
Rainfall
Skewness
Trends

ABSTRACT

Rainfall is an important factor for agriculture in India as nearly 60 per cent net arable land lacks irrigation and water availability determines the yield of pulses, rice, wheat and sugarcane. The variation of rainfall was one of the major concerns under present climatic situation challenging the farmers to obtain optimum farm production and maintain employment. Therefore, trend analysis was examined for long-term trends from 1975-2021 for rainfall at micro scale level of Madhira in Telangana state. In this study, average monthly and seasonal rainfall, coefficient of variation (CV) was ranging from 43.91 to 300.56 per cent and 27.44 to 171.87 per cent, respectively. The annual value of kurtosis and skewness were -0.39 and 0.47 which resembles light tailed to normal distribution and positively skewed resembling right to the mean. During monsoon, post monsoon and annual rainfall trends were showing non-significantly deceasing trend while winter and post monsoon showed non-significantly increasing trends but, as per Spearman's Rho (non parametric) tests significant increasing trend for winter season. Overall, the four decades of observations showed that there is alternate increasing and decreasing trend at Madhira for monsoon season. The post-monsoon season four decades showed negative departures and annual rainfall was mostly dominated by monsoon, a similar pattern was observed in it also.

Introduction

Climate is one of the important components in the earth system for agriculture. There are many parameters such as rainfall, temperature, humidity and atmospheric pressure that constitute weather and climate of a region. In all other weather parameters, rainfall is one of the most important parameters which decides the success or failure of agriculture production and productivity. Each year

Corresponding author E-mail: dharavathnaga@gmail.com
Doi:https://doi.org/10.36953/ECJ.13832414

variation in monsoon rainfall occasionally leads to extreme hydrological events such as large-scale floods and droughts, resulting in considerable reduction in agricultural production and affecting the many people (an extent of one billion) and national economy (Fasullo and Webster, 2003).A normal monsoon with widely distributed rainfall all over the country is a bonanza, while extreme flood or drought over large or a smaller region constitutes a natural hazard. The southwest (SW) monsoon brings around 80% of the total rainfall over the country. The changes in the frequency, pattern and variation of SW monsoon would have a significant impact on crop production, water availability and overall economy of most of the countries (Saha and Mooley, 1979; Sinha and Srivastava, 2000; Seoand Ummenhofer, 2017). Hence the variation in seasonal monsoon precipitation may be considered a measure to evaluate climate change/change over the Indian monsoon domain in the context of global warming (McCarthy*et al.*, 2001).Here some of the studies have described trends at large scale (Kumar *et al.*, 2010), regional scales (Duhan and Pandey, 2013) and at individual stations (Ranjan and Saha, 2022). Actually, local and regional scale analysis (Babar and Ramesh, 2013) was more applicable to devise-specific development and adaptation plans to mollify negative effects of climate change. Trend analysis of rainfall, temperature and other climatic parameters on different spatial scales may help in the establishment of future climate scenarios (Meshram *et al.,* 2018). Laskar *et al.* (2014) have performed trend analysis of temperature and rainfall of selected stations over north-east India and found a significantly decreasing trend of monsoon rainfall at Agartala during 1954-2012. Das *et al.* (2015) analyzed seasonal and yearly rainfall amounts for the two stations of Agartala and Passighat and no statistically significant trend was found.The major objective of the present study is to find whether there was any trend in the monthly, seasonal and annual rainfall pattern at Madhira, Khammam district of Telangana.

Material and Methods

The data was collected from the agrometeorological observatory, Agriculture Research Station (ARS), Madhira lying between 16.9182° N latitude, 80.3633° E longitude in Khammam district of Telangana state. The rainfall data was analyzed for monthly, seasonal and annual from 1975 to 2021 (47 years) using different types of statistical tools. The whole year was partitioned into four seasons by following India Meteorological Department, New Delhi norms. Winter season begins from January to February followed by summer season from March to May. Southwest monsoon starts from June to September followed by post monsoon in October and November. Trend was described as general movement of a series over an extended time period (Webber and Hawkins, 1980). The trend was determined by relationship between the received rainfall amount in mm and its temporal resolution. The mean, standard deviation (SD), coefficient of variation (CV) and Kurtosis and Skewness of rainfall were computed to analyze the relationship.

$$\text{Standard deviation } (s) = \sqrt{\frac{\sum_{i=1}^{n}(xi-\bar{x})^2}{n-1}}$$

$$\text{CV} = \frac{StandardDeviation}{Mean} \times 100$$

$$\text{Skewness (g)} = \frac{\sum_{i=1}^{n}(xi-\bar{x})^3}{(n-1)s^3}$$

$$\text{Kurtosis (K)} = n\frac{\sum_{i=1}^{n}(xi-\bar{x})^4}{(\sum_{i=1}^{n}(xi-\bar{x})^2)^2}$$

x_i= each value of the observation
$\bar{x}$= sample mean
n = total number of observations
s = standard deviation

The statistical methods like analysis of regression and coefficient of determination R^2 were used for deducing significance of rainfall trends. The trend analysis was derived and tested by Mann- Kendall (non parametric), Spearman's Rho (non parametric) and Linear regression (parametric) tests.The non parametric Mann- Kendall (M-K) test was proposed by Mann (1945) and was large-scale used with climatological time series. There are two advantages of this test. First one, it is non parametric test and does not necessarily need the data to be normally distributed. Second, the test has less sensitivity with abrupt breaks due to inhomogeneous time series. According to the test, null hypothesis

(H_0) assumes that there was no trend (data was independent and randomly ordered). It can be tested against the alternative hypothesis (H_1), which assumes that there was a trend. The Mann- Kendall statistic 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. Every data point's x_j was taken as a reference point,

$sgn\left(x_j - x_k\right) = 1$ if $x_j - x_j > 0$
$=0$ if $x_j - x_j = 0$
$= -1$ if $x_j - x_j < 0$

A higher positive value of S was an indicator of an increasing trend and lower negative value indicated a decreasing trend. The presence of a statistical significance trend was evaluated using Z value.Spearman's Rho (Sneyers, 1990 and Lehmann, 1975) test was one of the rank-based nonparametric methods used for trend analysis, applied as a comparison with the M-K test. The test assumes that time series data were independent and evenly distributed, the null hypothesis (H_0) again showed no trend over time, the alternate hypothesis (H_I) was that a trend existed and that data increased or decreased. The positive values represented an increasing trend over the time period and negative values represented the decreasing trends.

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

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

The parametric test, linear regression is assumed data to be normally distributed and examined whether there was a linear trend between time series (x) and variable of interest (y).The regression gradient was computed by,

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

The intercept was computed 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 followed a Student-t distribution with n-2 degrees of freedom. The linear regression test assumed that data was normally distributed. The trend was determined by Trend analysis software (Francis and Lionel, 2005).

The decadal variation of rainfall at Madhira station was studied for the four decades 1981-90, 1991-00, 2001-10 and 2011-20.

Results and Discussion

This section describes rainfall analysis mean, SD, coefficient of variation, kurtosis and skewness of monthly and seasonal rainfall; assessment rainfall trends monthly, seasonal and annual through M-K (nonparametric), Spearman's Rho (nonparametric), linear regression (parametric) methods and decadal variation of rainfall. The descriptive statistics information of rainfall like maximum and minimum received rainfall, mean, SD, coefficient of variation, kurtosis and skewness were presented in Table 1. Here in computed table, it was identified that the average annual maximum, minimum and mean rainfall were 1609.6, 529.8 and 982.4 mm, respectively. The mean highest and lowest monthly rainfall were 226.5 mm and 6.1 mm in the month of August and February, respectively and mean seasonal highest and lowest rainfall was 720.5 mm and 71.2 mm during monsoon and pre monsoon period. The average monthly and seasonal SD range observed was13.42 to 114.30 mm and 64.02 to 269.57 mm, respectively. Average monthly and seasonal rainfall CV was ranging from 43.91 to 300.56 per cent and 27.44to 171.87 per cent, respectively.Similar results were reported by Guhathakurta *et al.* (2020) with highest contribution to the southwest monsoon rainfall was 30.5 % in the month of August followed by 29.7 %, 21.2 %, and 18.6 % in the months of July, September and June respectively. Telangana state received annual rainfall about 78.8 % from southwest monsoon. The CV of monsoon was 22.5 % and annual rainfall for Telangana state was 20.5 %.

Table 1: Historically (1975-2021) rainfall analysis mean, standard deviation, coefficient of variation (CV), kurtosis and skewness for monthly, seasonal and annual rainfall

Parameters	Maximum (mm)	Minimum (mm)	Mean (mm)	SD (mm)	CV (%)	Kurtosis	Skewness
Jan	51.4	0.0	6.2	13.42	217.95	4.56	2.34
Feb	102.7	0.0	6.1	18.19	300.56	18.73	4.13
March	67.4	0.0	10.4	19.16	184.27	2.77	2.00
April	73.6	0.0	15.8	21.88	138.52	1.56	1.55
May	268	0.0	46.0	55.18	120.03	6.28	2.28
June	277.1	1.2	120.8	81.57	67.54	-1.00	0.33
July	553.6	76.8	213.9	103.72	48.48	2.47	1.47
Aug	465.9	44.6	226.5	99.46	43.91	0.38	0.69
Sept	356	0.0	159.3	86.75	54.46	-0.55	0.45
Oct	472.6	0.0	130.8	114.30	87.36	0.74	1.19
Nov	392	0.0	39.4	69.14	175.46	14.50	3.41
Dec	87.3	0.0	8.3	19.38	234.43	8.57	2.97
Winter	102.7	0.0	12.2	20.98	171.87	6.84	2.39
Pre monsoon	335.4	0.0	71.2	64.02	89.93	6.41	2.17
Monsoon	1363.5	398.0	720.5	220.95	30.67	0.34	0.65
Post monsoon	493.4	0.0	178.5	129.81	72.73	-0.18	0.86
Annual	1609.6	529.8	982.4	269.57	27.44	-0.39	0.47

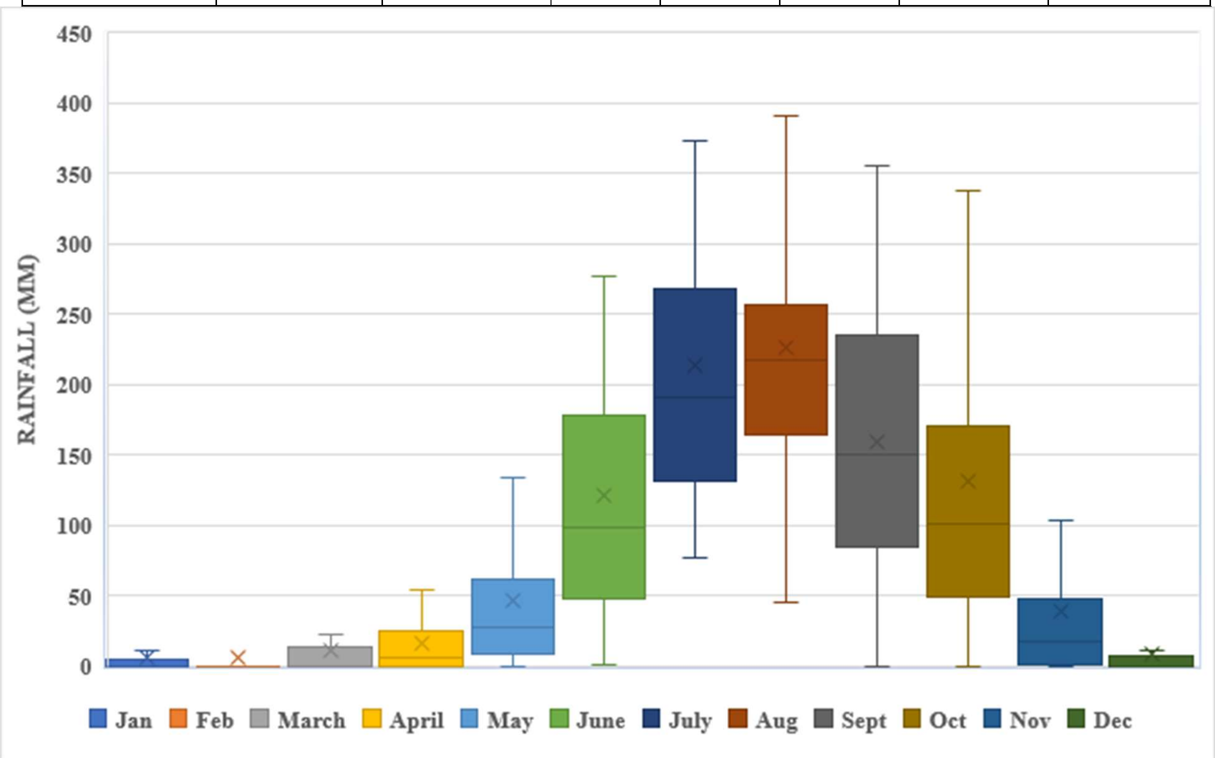

Figure 1: Monthly rainfall (mm) in Box and whisker plot for Madhira station from 1975 to 2021

Kurtosis measures of whether the rainfall data were heavy to light tailed against normal distribution. The data sets with excess kurtosis tend to have outliers or heavy tails. Data sets with lower kurtosis tend to have a lack of outliers or light tails with identical distribution being an extreme case. The highest and lowest values of coefficient of kurtosis were found as 18.73 and -1.00 for the month of February and June resembling heavy tailed and light tailed respectively. The highest and lowest values were found as 6.41 and -0.18for pre and post monsoon seasons that were heavy and light tailed respectively. The annual value of kurtosis was -0.39 which overall resembled light tailed to nearly normal distribution. Skewness measures symmetry or more accurately the lack of symmetry. A data set or distribution is symmetric whether it looks the same to the left and right from centre point. The skewness was found to be high for the month of February with4.13 representing asymmetry and low for the month of June with0.33 representing nearer to symmetry. For the season winter, skewness was high at 2.39 resembling positively skewed and the monsoon season was low at 0.65 even though it was positively skewed. The annual value was 0.47 indicated positively skewed resembling the right of the mean. Similar study analyzed by Vishnuvardhan *et al.* (2020) and observed that kurtosis was having an annual value of 0.23 in contrast to the present study, indicating slightly leptokurtic in nature. Skewness was the mean predominantly positive skewness of average annual value 0.44 representing annual rainfall in the region (YSR Kadapa district, AP) was asymmetric and it lied to the right of the mean that was right skewed which was similar to the present study.

Rainfall trend

Monthly rainfall

Figure 2 showed that the monthly rainfall pattern revealed that excess amounts of rainfall occur in SW monsoon months that were from June to September at Madhira station, monthly rainfall analysis was presented in Table 2. In these results, it was observed that January, February, March, May, June, September and December months showed non significantly increasing trend while April, July, August, October and November district showed non significantly increasing trend. In Telangana state, non-significant increasing trend was observed for the Khammam district and all other districts showed significantly decreasing trend for the rainfall month of June. Khammam district indicated non-significantly decreasing trend while all other districts indicated significantly decreasing trend in rainfall for the month of July and August (Guhathakurta *et al.*, 2020).

Seasonal rainfall trend

Winter

The rainfall trends graphically presented in Figure 2 showed an increasing trend of winter rainfall at Madhira, where the linear regression equation indicated positive slope value (b =0.035) and R^2 value was0.00. R^2 the coefficient of determination value explained that no variance in winter rainfall was elucidated by the linear regression model. In Table 2, Spearman's Rho (non parametric) tests showed that there was significance of increasing trend at 1.00per cent level and other two tests showed no significance. Krishnakumar *et al.* (2009) also reported an increasing trend in winter rain events in Karnataka state.

Pre monsoon

The rainfall trends in Figure 3 showed that there was an increasing trend of pre monsoon rainfall at Madhira and the linear regression equation showed positive slope value (b = 0.155), R^2 value of 0.001. R^2 was 0.1 % of variability in winter rainfall explained by the linear regression model. In Table 2 all three rainfall trend tests showed insignificance. Analysis of trend by Dash *et al.* (2011) represented that during the summer monsoon, short spell rain activities with high intensity increased over India as a whole.

Monsoon / Southwest monsoon

The rainfall trends in Table 2showedno significant increasing trend for M-K and Spearman's Rho tests and decreasing trends for in Linear regression test during pre monsoon rainfall at Madhira, but in the Figure 4 linear regression equation was indicating negative slope value (b = - 0.522), theR^2 value was 0.001. R^2 explained that 0.1 % of variability in monsoon rainfall was explained by this linear regression model. For the SW monsoon season, Khammam district indicated the non-significantly decreasing trend and these results were similar to the analysis of Guhathakurta *et al.* (2020).The decrease in standard precipitation index (SPI)

Table 2: Assessment rainfall of monthly, seasonal and annul through parametric and non parametric methods

Parameters	Mann- Kendall (Non parametric)	Spearman's Rho (Non parametric)	Linear regression (Parametric)
Jan	0.779	0.911	0.929
Feb	0.128	4.203	-0.650
March	1.366	3.444	0.871
April	-0.028	0.795	0.005
May	0.000	0.158	-0.043
June	0.779	0.911	0.929
July	-0.367	-0.461	-0.340
Aug	-1.376	-1.383	-0.949
Sept	0.138	0.167	0.064
Oct	-1.000	-1.141	-1.038
Nov	-0.908	-0.776	-1.426
Dec	0.202	3.172	1.074
Winter	0.569	3.085***	0.153
Pre monsoon	0.734	0.815	0.224
Monsoon	0.22	0.049	-0.217
Post monsoon	-1.623	-1.734	-1.526
Annual	-0.651	-0.718	-0.836

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

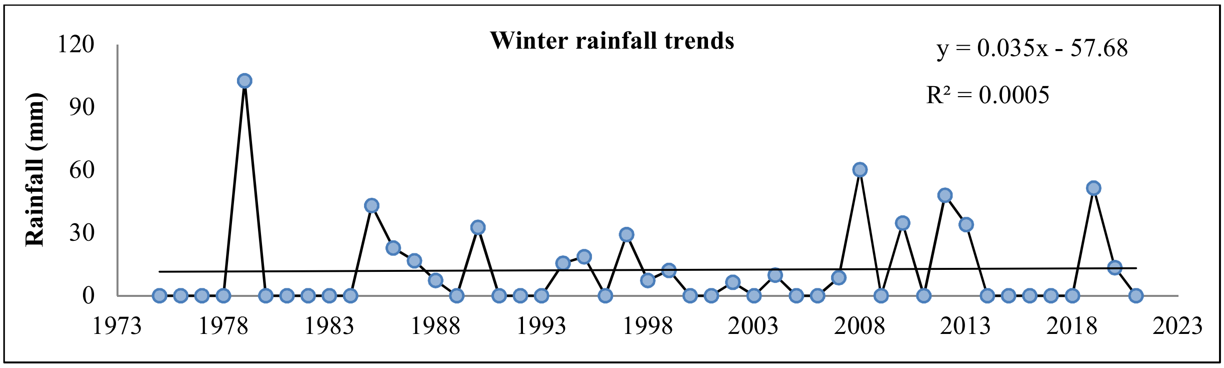

Figure 2: Winter rainfall trends at Madhira from 1975 to 2021

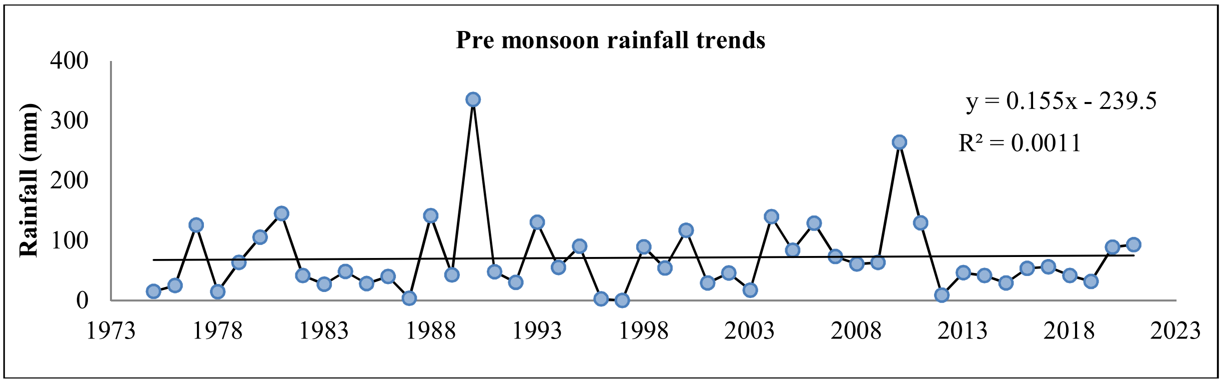

Figure 3: Pre monsoon rainfall trends at Madhira from 1975 to 2021

values were observed over most of the districts of central India and endmost south peninsular India during June, July and September months, while in the month of August it was over eastern, north-eastern and Tamil Nadu region (Guhathakurta, 2017).

Post Monsoon

In Figure 3 rainfall trend was showing general decreasing trend for all three tests during post monsoon at Madhira, where linear regression equation was indicating negative slope value (b = -2.099), R^2 value was 0.049. $R^2$was explained that 4.9% of variability in the monsoon rainfall was elucidated by the linear regression model. In over all, all three rainfall trend tests as given in Table 2 were showed insignificance. Guhathakurta *et al.* (2020) in their analysis indicated that the monthly rainfall did not indicate any significant increasing or decreasing trend while seasonal or annual rainfall indicated non-significant decreasing trend.

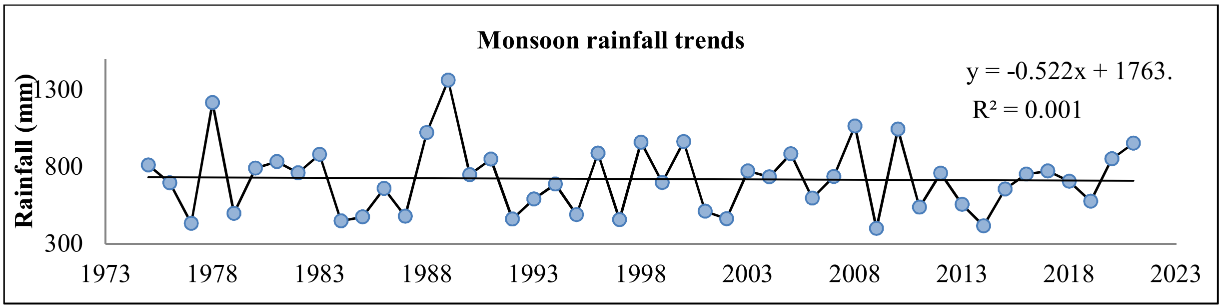

Figure 4: Monsoon rainfall trends at Madhira from 1975 to 2021

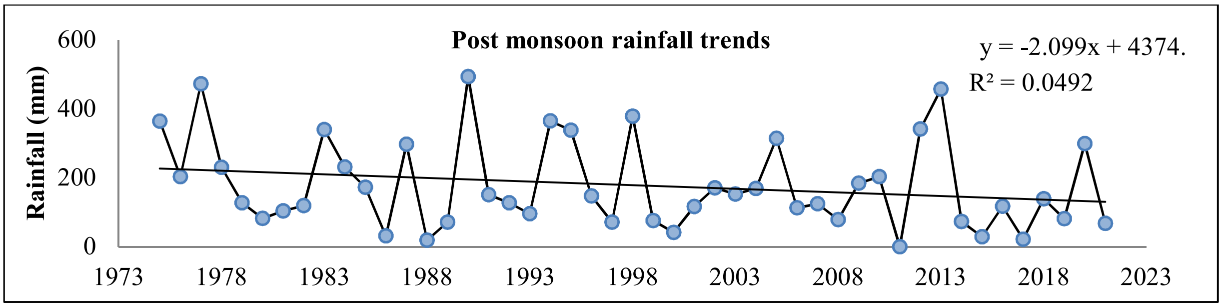

Figure 5: Post monsoon rainfall trends of Madhira from 1975 to 2021

Annual rainfall trend

Figure 6 showed the general decreasing trend of annual rainfall at Madhira, where the linear regression equation was negative slope value of b = - 2.431 and the R^2 value was 0.015. R^2 showed 1.5 % variability in the annual rainfall as shown in the linear regression model. In Table 2, all rainfall trend test methods showed that there was insignificance of decreasing trend. The analysis indicated that neither monthly or seasonal nor annual rainfall for the state as whole rainfall showed any statistically significant increasing/decreasing trend. Guhathakurta *et al.* (2020) also stated that seasonal (SW) or annual rainfall show non-significant decreasing trend for Telangana state.

Decadal variation in rainfall

Apart from the annual variation in rainfall, it was observed that southwest monsoon rainfall exhibited significant multi decadal variations in the Indian region (Guhathakurta and Rajeevan, 2008). In view of the importance of decadal variation in rainfall, many researchers have studied the same using different scales.Guhathakurta *et al.*, 2014 have studied such variation for Indian summer monsoon rainfall and stated that there was a decreasing trend in decadal rainfall during the period 1961-2010. At micro scale (station level), studies on decadal variability of rainfall were carried out by Seetharam (2003) for Jalpaiguri and Kavi (1988) for Bangalore.

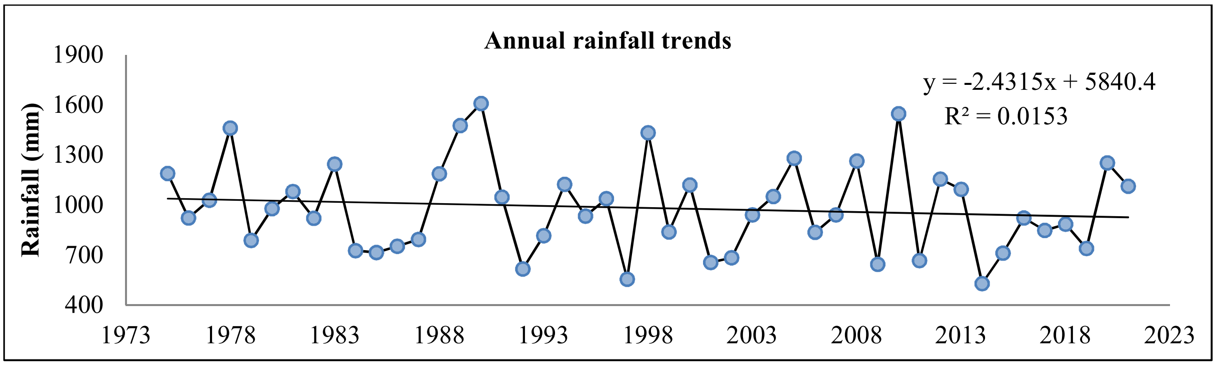

Figure 6: Annual rainfall trends of Madhira from 1975 to 2021

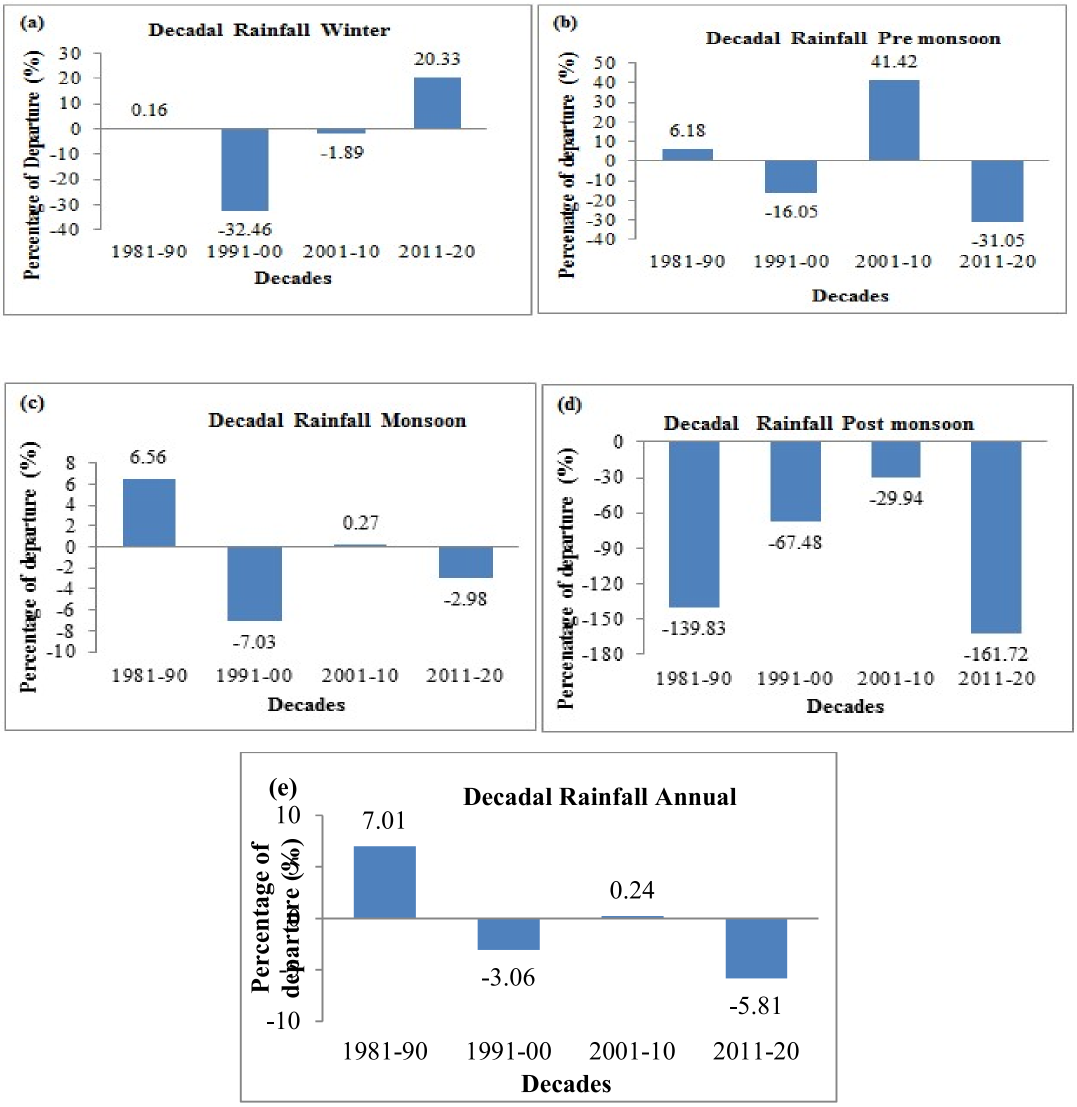

Figure 6(a-e): Plots of decadal variation in rainfall at Madhira

A similar attempt was made here at Madhira to study for the decades 1981-90, 1991-00, 2001-10 and 2011-20. It was observed from Figure 6 that during the winter season, decadal rainfall departures mostly showed deep negative departure during the decade 1991-00 and positive departure during 2011-20. However, significant positive of 41.42 per cent and negative of 31.05 per cent, departures were observed during the decades 2001-10 and 2011-20 respectively for pre monsoon season. Similar trend was observed for winter and pre monsoon season for the decades of 1981-90 and 1991-00.The monsoon season of 1991-00 showed the highest negative at Madhira station in the period of study. Similarly, *vice-versa* was observed during the decade 1981-90, which was the decade with highest positive departure for Madhira station. The overall observation of all decades showed an alternate increasing and decreasing trend at Madhira during the period of study for the monsoon season. For the post-monsoon season from 1981-90 to 2011-20 all decades were showing negative departures fall on the same side of the axis and highest negative departure (161.72 per cent) was observed for the decade of 2011-20. Since the annual rainfall is mostly dominated by monsoon so that a similar pattern is observed in annual rainfall also.Similar observations were also studied by Ranjan and Saha (2022) for rainfall trend over Tripura dominated by monsoon season that majorly influencing annual rainfall.

Conclusion

In the present rainfall analysis, an attempt has been made to find the trends at Madhira station, Khammam district of Telangana at micro scale level variations during the period 1975-2021. The CV, kurtosis and skewness were computed along with trend analysis and decadal variation of rainfall. The average monthly and seasonal rainfall CV ranged from 43.91 to 300.56 per cent and 27.44to 171.87 per cent respectively. The annual value of kurtosis and skewness were -0.39 and 0.47 which overall resembles light tailed to normal distribution and positively skewed to the right of the mean. During monsoon, post monsoon seasons and annual rainfall, the trends were showing non-significantly decreasing trends while winter and post monsoon were showing non-significantly increasing trends. But as per Spearman's Rho (non parametric) tests there was a significant increasing trend for the winter season. Overall, the decades of observations showed an alternate increasing and decreasing trend at Madhira during the period of study for the monsoon season. For the post-monsoon season all four decades showed negative departures. The annual rainfall was mostly dominated by monsoon and a similar pattern was observed in annual rainfall also.

Acknowledgement

The authors are very thankful to India Meteorological Department (IMD), New Delhi, Met Centre, Hyderabad, Agro Climate Research Centre, Hyderabad and Regional Agriculture Research Centre, Warangal for their constant motivation and guidance to carry out the work. The authors are also thankful to the Agriculture Research Station (ARS), Madhira for providing historical rainfall data and gratitude to all the people who have made this study possible.

Conflict of interest

The authors declare that they have no conflict of interest.

References

Addisu, S., Selassie, Y.G., Fissha, G. & Gedif, B. (2015). Time series trend analysis of temperature and rainfall in lake Tana sub-basin, Ethiopia. *Environmental Systems Research,* 4(1), 25.

Das, S., Tomar, C. S., Saha, D., Shaw, S. O. &Singh, C.(2015). Trends in Rainfall Patterns over North-East India during 1961-2010. *International Journal of Earth and Atmospheric Science,*2, 37-48.

Dash, S. K., Nair, A. A., Kulkarni, M. A. & Mohanty, U. C. (2011). Characteristic changes in the long and short spells of different rain intensities in India. *Theoretical Applied Climatology*, 105,563 - 570.

Duhan, D. & Pandey, A. (2013). Statistical analysis of long term spatial and temporal trends of precipitation during 1901-2002 at Madhya Pradesh, India. *Atmospheric Research*, 122, 136-149.

Fasullo, J. & Webster, P.J. (2003).A hydrological definition of Indian Monsoon onset and withdrawal. *Journal Climate*, 16, 3200–3211.

Francis, C. & Lionel, S. (2005). Trend/change detection software user guide. CRC for Catchment Hydrology's (CRCCH) Climate Variability Program, Australia.

Guhathakurta, P., Menon P., Inkane, P.M., Krishnan, U. & Sable, S.T. (2017). Trends and variability of meteorological drought over the districts of India using standardized precipitation index. *Journal Earth System Science,* 126(120), 6-18.

Guhathakurta, P. & Rajeevan, M., (2008). Trends in the rainfall pattern over India*, International Journal of Climatology,* 28, 1453-1469.

Guhathakurta, P., Sanap, S., Menon, P., Prasad, A.K., Sable, S.T. & Advani, S. C. (2020). Observed rainfall variability and changes over Telangana State. *ESSO/IMD/HS/Rainfall Variability/25(2020)/49*. Pp-23.

Kumar, V., Jain, S.K. & Singh, Y. (2010). Analysis of long term rainfalltrends in India. *Hydrological ScienceJournal,* 55(4), 484–496.

Karanurun, A. & Kara, F. (2011). Analysis of spatially distributed annual, seasonal and monthly temperatures in Istanbul from 1975to 2006.*World Applied Science Journal,* 12(10), 1662–1675.

Krishnakuma, K. N., Rao, G.S.L.H.V.P. & Gopakumar, C. S. (2009). Rainfall trends in twentieth century over Kerala, India. *Atmospheric Environment,* 43, 1940–1944.

Laskar, S. I., Kotal, S. D. & Roy Bhowmik, S. K.(2014).Analysis of rainfall and temperature trends of selected stations over North East India during last century. *Mausam*, 65, 497-508.

Lehmann, E. L. (1975). Non parametrics, Statistical Methods Based on Ranks, Holden-Day, San Francisco, Calif, USA.

Mann, H. B., (1945). Nonparametric tests against trend. *Econometrica,* 13, 245-259.

McCarthy, J., Canziani, O., Leary, N., Dokken, D.& White, K. (2001). Climate change 2001: impacts, adaptation, and vulnerability. Contribution of working group II to the fourth assessment report of the intergovernmental panel on climate change; Cambridge University Press: Cambridge, UK, 2001.Pp. 19–25.

Meshram, S.G., Singh, S.K., Meshram, C., Deo, R.C. & Ambade, B.(2018) Statistical evaluation of rainfall time series in concurrence with agriculture and water resources of Ken River basin, Central India (1901–2010). *Theoretical and Applied Climatology*, 134, 1231–1243.

Saha, K.R. &Mooley, D.A. (1979). The Indian monsoon and its economic impact. *GeoJournal*, 3(2), 171–178.

Seo, H. &Ummenhofer, C. (2017). Intra-seasonal rainfall variability in the Bay of Bengal during the summer monsoon: Coupling with the ocean and modulation by the Indian Ocean dipole. *Atmospheric Science Letters*, 18, 88–95.

Seetharam, K.(2003). Inter annual and intra decadal behaviour of monsoon rainfall over Jalpaiguri. *Mausam*, 54(2), 539-541.

Sinha, K.C. & Srivastava, A.K. (2000). Is there any change in extreme events like heavy rainfall? *Current Science*, 79,155–158.

Sneyers, R.(1990). On the statistical analysis of series of observations. World Meteorological Organization. *Technical Note,* 143:WMO no. 415.

Ranjan, P. &Saha, D. (2022).Analysis of rainfall trends over Tripura. *Mausam*, 73(1), 27-36.

Vishnuvardhan, V., Venkatesh, M., Rakesh, P., Sagar V. & Swaroop, V. (2020). Statistical analysis of 30 years rainfall data of YSR Kadapadistrict, Andhra Pradesh, India. *Paideuma Journal,* 13(3), 120-125.

Webber, J. & Hawkins, C. (1980). Statistical analysis application tobusiness and economics. New York: Harper and Row.

Publisher's Note: ASEA remains neutral with regard to jurisdictional claims in published maps and figures.