

Trend Analysis of Rainfall Patterns in Rajnandgaon District, Chhattisgarh

ABSTRACT

Climate is a crucial factor that determines the type of vegetation, wildlife, and livability of an area. It encompasses the long-term characteristics of the atmosphere and its fluctuations. Precipitation, specifically rainfall, plays a vital role in the Earth's hydrological cycle and serves as a connection between weather, climate, and water resources. The focus of this study is the Rajnandgaon district in Chhattisgarh, India. The average annual precipitation in this region amounts to 1274mm. By analyzing trends, it is possible to ascertain whether certain properties are increasing or decreasing over time. The findings of this study reveal that the coefficient of variation, which measures the variability, is lower during the months of June, July, August, and September ($CV < 76\%$). Monsoon rainfall exhibits the least variability with a coefficient of variation of 30.88, while pre-monsoon rainfall has a coefficient of variation of 33.83%. In contrast, winter rainfall displays the highest coefficient of variation at 208.48%. Furthermore, the analysis demonstrates a significant decreasing trend in annual, monsoon, and September rainfall. However, May rainfall has shown a significant increase at a 5% level of significance. To conduct this analysis, the non-parametric Mann-Kendall and Sen's Slope Estimator tests were employed, utilizing monthly rainfall data from 1988 to 2018 for the Rajnandgaon district of Chhattisgarh.

Keywords: Climate, Rainfall, Trend Analysis and Non Parametric Test

INTRODUCTION

Climate is the atmospheric condition at a specific location, encompassing information about the types of plants, animals, and suitability for human habitation. It represents a long-term summary of various atmospheric factors and their fluctuations, including solar radiation, temperature, humidity, rainfall, atmospheric pressure, wind, and its direction. Rainfall plays a crucial role in transporting water from the atmosphere to the Earth's surface, connecting weather patterns, climate, and the hydrological cycle. In the case of India, precipitation holds

significant importance for regional climate, annual crops, food production, local economy, and has therefore been the subject of numerous studies analyzing long-term trends.

The Indian climate is predominantly influenced by the southwest monsoon, with around 80% of rainfall occurring during the four monsoon months (June-September) and exhibiting substantial spatial and temporal variations across the country. Precipitation in India primarily takes the form of rainfall. One of the challenges posed by climate variability is identifying and quantifying trends in rainfall, as well as understanding their implications for river flows. Analyzing these trends helps in effective water resource management and the formulation of appropriate adaptation strategies. The scientific community has placed significant attention on rainfall trend analysis in the past century due to the global focus on climate change (IPCC, 1996).

Trend analysis provides insights into whether concentrations of rainfall are increasing or decreasing over time. It serves as a key tool for predicting rainfall patterns and rainy days in a particular area, facilitating planning for agricultural activities based on yearly and monthly rainfall and rainy day data.

STUDY AREA

The study area is Rajnandgaon district, located in the state of Chhattisgarh, India. It was established on 26 January 1973 through the division of Durg district. Rajnandgaon is a large district spanning 8022.55 square kilometers and is situated between 21.10° N Latitude and 81.03° E Longitude. It has an average elevation of 307 meters and receives an annual precipitation of 1274mm. The district is surrounded by Kabirdham district to the North, Bastar district to the South, Durg district to the East, and Gadchiroli and Bhandara districts of Maharashtra state, as well as Balaghat district of Madhya Pradesh state to the West.

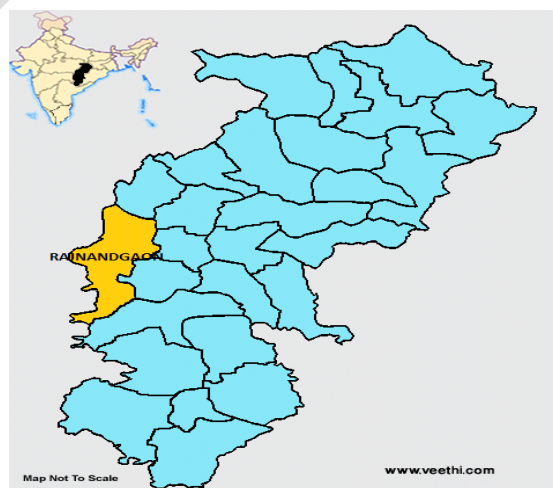


Fig. 1: Map of Rajnandgaon district in Chhattisgarh and India map



Fig. 2: Map of Rajnandgaon District

METHODOLOGY

Non-parametric statistical methods were utilized to analyze meteorological data, specifically rainfall and rainy days, in the study area. These methods are better suited for non-normally distributed data compared to parametric statistical tests.

The Mann Kendall (MK) test is the most commonly used non-parametric statistical tool for detecting trends in hydro-meteorological time series variables such as water quality, stream-flow, temperature, and precipitation. The tests employed include the Mann-Kendall test for identifying consistent trends, Sen's slope test for measuring the magnitude of slope, and Wilcoxon Mann-Whitney step trend analysis.

A trend refers to a significant change over time observed in a random variable. Typically, the magnitude of a trend in a time series is determined either through regression analysis (a parametric test) or the Mann-Kendall test (a non-parametric method). Both of these methods assume a linear trend in the time series. In this particular study, both linear regression and the Mann-Kendall test were used. The trend analysis was conducted on an annual basis as well as a seasonal basis. Meteorologically, a year is categorized into four seasons: southwest monsoon season (June-Sep), post-monsoon season (Oct-Dec), winter season (Jan-Feb), and summer season (Mar-May).

Mean rainfall:

The amount of rain accumulated in a rain gauge within 24 hours is called daily rainfall, while the total collected in a year is referred to as annual rainfall. The average annual rainfall over 31 years in India is known as the mean annual rainfall or normal annual rainfall.

$$\text{Mean annual rainfall} = \frac{\text{Total rainfall}}{\text{Number of years}}$$

Standard Deviation:

Standard deviation represents the square root of the average of squared differences between rainfall values and their mean, indicating variability or dispersion. Its formula is as follows.

$$SD = \sqrt{\frac{\sum_{i=1}^n (X_i - \bar{X})^2}{n - 1}}$$

Where,

X_i = rainfall frequency, \bar{X} = mean rainfall, n = numbers of year

Variability analysis (Coefficient of variation):

Assessment of rainfall variability through Coefficient of variation (CV %) appears to be simple. CV is defined as the Standard deviation divided by the mean value of rainfall. It shows the variability of rainfall in percentage.

$$CV = \frac{\sigma}{\bar{X}} \times 100 \%$$

The greater the CV, the lesser the dependability of receiving rainfall. Considering the annual CV, the IMD is using the following criteria for assessing the rainfall in a particular area.

Normal = - 19 to 19 % of annual normal rainfall.

Deficit = - 20 to - 59 % of annual normal rainfall.

Scarce = - 60 % and above of annual normal rainfall

A trend is a notable change in a random variable over time. Trend magnitude is typically assessed using regression analysis or Mann Kendall's non-parametric test, with the latter being used in this study. The non-parametric tests used are listed below.

NON- PARAMETRIC TREND TEST-

- **Mann-Kendall Analysis :**

Mann-Kendall's test is a non-parametric method, which is less sensitive to outliers and test for a trend in time series without specifying whether the trend is linear or non-linear .

The Mann-Kendall's test statistic is given as:

$$S = \sum_{i=1}^{n-1} \sum_{j=1}^n \text{sgn}(x_j - x_i)$$

Where S is the Mann-Kendall's test statistics;

x_i and x_j are the sequential data values of the time series in the years i and j ($j>i$) and 'n' is the length of the time series.

A positive (S) value indicates an increasing trend and a negative value indicates a decreasing trend in the data series.

The sign function is given as:

$$\text{Sgn}(x_j - x_i) = \begin{cases} +1 & \text{if } (x_j - x_i) > 0 \\ 0 & \text{if } (x_j - x_i) = 0 \\ -1 & \text{if } (x_j - x_i) < 0 \end{cases}$$

The variance of S, for the situation where there may be ties (that is equal values) in the x values, is given by:

$$V(s) = \frac{n(n-1)(2n+5) - \sum_{p=1}^g t_p(t_p-1)(2t_p+5)}{18}$$

Where, g = Number of tied groups, t_p = Number of data values in the p^{th} group.

n = Number of years data.

For (n) larger than 10, approximates the standard normal distribution and computed as follows:

$$Z_{mk} = \begin{cases} \frac{S-1}{\sqrt{\text{var}(s)}} & ; \text{if } S > 0 \\ 0 & ; \text{if } S = 0 \\ \frac{S+1}{\sqrt{\text{var}(s)}} & ; \text{if } S < 0 \end{cases}$$

The presence of a statistically significant trend is evaluated using the Z_{mk} value. A positive/negative value of Z indicates an upward/downward trend. In a two-sided test for trend, the null hypothesis H_0 should be accepted if $Z_{mk} < Z_{(1-\alpha)/2}$ at a given level of significance. $Z_{(1-\alpha)/2}$ is the critical value of Z_{mk} from the standard normal table.

- **Sen's slope :**

The magnitude of slope of trend is estimated using the approach. The Sen's slope estimator is a non-parametric, linear slope estimator that works most effectively on monotonic data.

The Sen's slope technique is used to determine the magnitude of the trend line. This test computes both the slope (i.e. linear rate of change) and intercept according to Sen's method. First, a set of linear slopes is calculated as follows:

$$\text{Median}(d_k) = \frac{(X_j - X_i)}{(j - i)}, \quad \text{for } (1 \leq i < j \leq n),$$

Where,

d = is the slope, X = denotes the variable, n = is the number of data, and i, j = are indices.

Sen's slope is then calculated as the median from all slopes: $b = \text{median}(d_k)$.

Where,

b = is estimate of the slope of trend and X_i = is the j^{th} observation.

A positive value of b indicates an upward trend. Where as a negative value represents a downward trend.

The intercepts are computed for each timestep "t" as given by:

$$a_t = X_t - b \times t$$

- **Spearman's rho (SR) test :**

After, the MK test has been popularly used to assess the significance of trends in hydro-meteorological time series, the SR test is seldom used in hydro-meteorological trend analysis.

$$D = 1 - \frac{6 \sum_{i=1}^n [R(x_i) - i]^2}{n(n^2 - 1)}$$

Where, $R(x_i)$ is the rank of i^{th} observation x_i in the sample of size n .

Under the null hypothesis, the distribution of D is asymptotically normal with the mean and variance as follows :

$$E(D) = 0$$

$$V(D) = \frac{1}{n - 1}$$

RESULTS AND DISCUSSION

This chapter presents the findings of a comprehensive analysis conducted on 31 years of rainfall and rainy days data. The results are discussed in relation to relevant literature, covering the following aspects.

Table 1: Monthly rainfall statistics for the period (1988-2018) of Rajnandgaon district of Chhattisgarh

Month/ Period	Mean monthly rainfall (mm) (1988-2018)		
	Mean (mm)	CV (%)	Contribution (%)
JAN	2.80	146.55	0.29
FEB	3.26	177.91	0.33
MAR	21.85	65.41	2.25
APR	12.14	88.53	1.25
MAY	18.17	61.48	1.88
JUN	153.58	21.74	15.86
JUL	306.00	28.36	31.60
AUG	223.59	25.37	23.08
SEP	170.15	25.87	17.56
OCT	55.23	82.60	5.70
NOV	0.31	323.84	0.03
DEC	1.35	382.80	0.14
ANNUAL	968.43	32.93	100
MONSOON	754.98	30.88	77.95
PRE-MONSOON	205.75	33.83	21.24
WINTER	7.74	208.48	0.80

The standard deviation (SD) and coefficient of variation (CV) of the monthly rainfall indicate high degree of variability associated in the monthly rainfall in all the months.

Table showed the mean, CV % contribution (%) of rainfall. The average annual rainfall of Rajnandgaon district in Chhattisgarh for 31 years from 1988-2018 was 968.43mm, and 32.93 was CV and contribution (100%) and their corresponding % contribution respectively. Monthly average rainfall was, were maximum (306.00 mm) in the month of July and minimum (0.31 mm) in the month of November. In case of seasonal rainfall, their values for monsoon, pre-monsoon and winter were 754.98, 205.75 and 7.75 mm respectively. The CV and % contribution value for seasonal rainfall were 30.88, 33.83 and 208.48 while % contribution 77.95, 21.24 and 0.80 respectively for monsoon, pre-monsoon and winter.

The monsoon season contributes maximum to annual rainfall in the districts. More rainfall occurs in the south-west monsoon (June, July, August and September) while other months also contributes to average annual rainfall but their contributions was least with respect to amount of rainfall.

TREND ANALYSIS OF MONTHLY RAINFALL

The rainfall data set of Rajnandgaon district for the period from 1988-2018 have been divided in three time series to know the trend of rainfall of two different time series and also compare the trend so; (i) for the period of 1988-2018; (ii) for the period of 1988-2003; (iii) for the period of 2004-2018 and have been analyzed separately.

Table 2: Trend analysis of monthly rainfall

MONTH/ PERIOD	1988-2018			1988-2003			2004-2018		
	MK	SR	SS	MK	SR	SS	MK	SR	SS
JAN	0.00	0.02	0.00	0.17	0.27	0.00	-0.21	-0.27	0.00
FEB	0.06	0.09	0.00	-0.09	-0.11	-0.01	0.00	0.01	0.00
MAR	0.10	0.14	0.13	0.30	0.39	1.40	-0.02	-0.04	-0.05
APR	0.55	0.05	0.05	-0.16	-0.27	-0.34	-0.03	-0.07	-0.09
MAY	-0.10	-0.16	-0.14	0.06	0.09	0.02	0.06	0.08	0.20
JUN	-0.10	-0.15	-0.58	0.02	0.01	0.33	0.05	0.07	0.35
JUL	-0.03	-0.06	-0.26	-0.02	-0.08	-0.42	-0.25	-0.37	-4.00
AUG	-0.12	-0.16	-0.86	0.30	0.46	5.64	0.17	0.24	1.59
SEP	-0.22	-0.32	-1.62	0.19	0.23	1.79	0.09	0.13	0.43
OCT	0.03	0.01	0.26	-0.13	-0.24	-1.44	-0.08	-0.12	-1.53
NOV	-0.08	-0.10	0.00	0.10	0.11	0.00	-0.27	-0.35	0.00
DEC	0.18	0.23	0.00	0.07	0.08	0.00	0.12	0.14	0.00

Here:

MK= Mann-Kendall test, SR= Spearman's rho test, SS= Sen's slope

Observing the analysis separately, the values from 1988 to 2018 show a negative trend in September but a positive trend in both 1988-2003 and 2004-2018. Similarly, all values in July exhibit a downward trend.

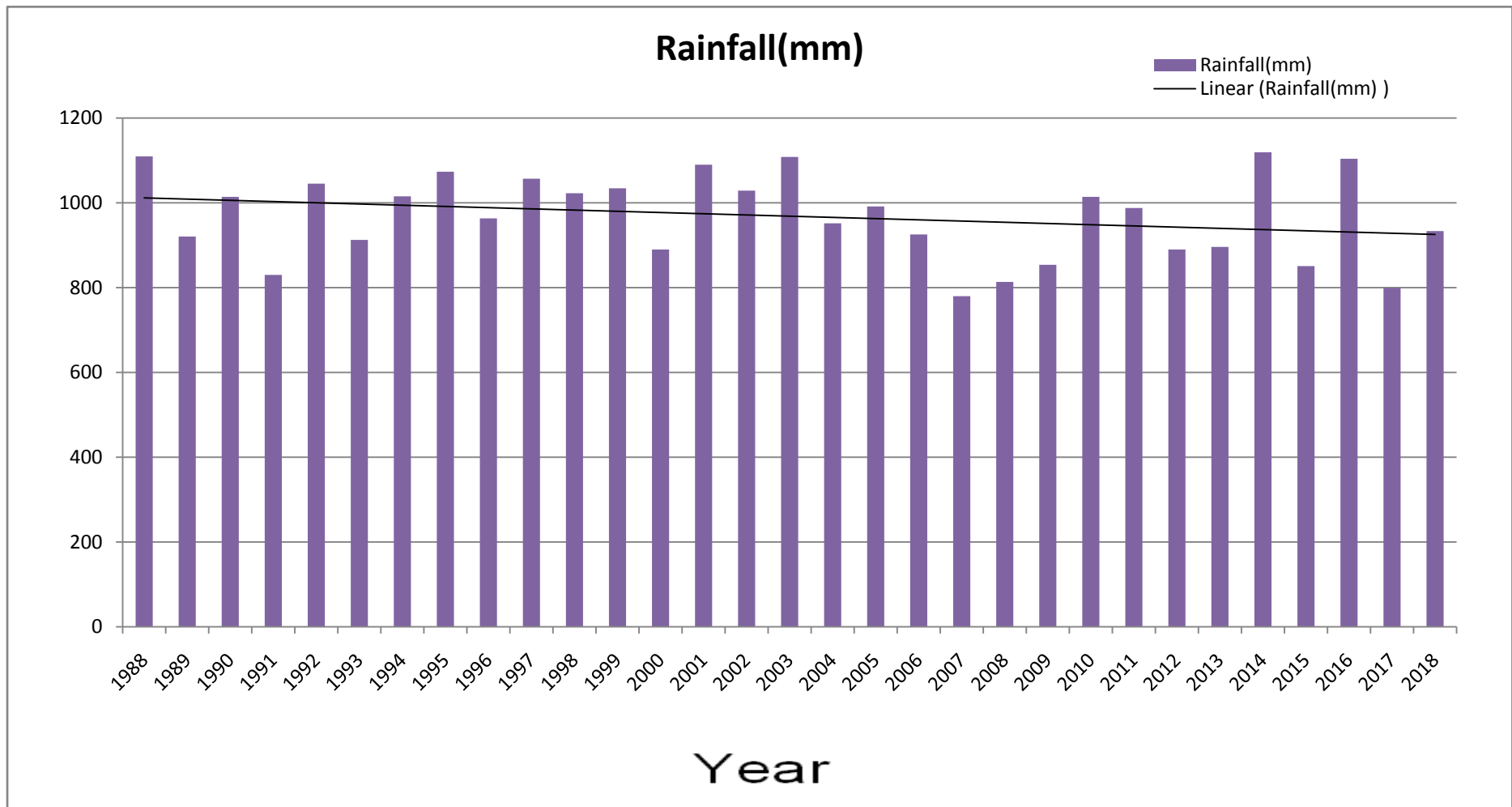


Fig.3: Annual Rainfall trend of Rajnandgaon

Conclusion

The findings of this study reveal interesting patterns in the monthly rainfall data for Rajnandgaon district of Chhattisgarh from 1988 to 2018. It has been determined that the coefficient of variation, a measure of variability, is relatively low during the months of June, July, August, and September ($CV < 76\%$). Furthermore, the monsoon rainfall exhibits the least variability with a coefficient of variation of 30.88, compared to the pre-monsoon period with a coefficient of variation of 33.83%. Conversely, the winter rainfall experiences the highest variability, with a coefficient of variation of 208.48%.

Through the application of the non-parametric Mann-Kendall and Sen's Slope Estimator tests, trend analysis was conducted on the rainfall data. The results indicate a significant decreasing trend in annual, monsoon, and September rainfall. However, it is worth noting that May rainfall has shown a significant increase at a 5% level of significance.

These findings provide valuable insights into the rainfall patterns of Rajnandgaon district and contribute to a better understanding of the local climate dynamics.

References

- Akinyemi, O., Ayeni, O. A., Faweya, O. and Ibraheem, A.G. 2013. Statistical study of annual and monthly rainfall patterns in Ekiti state, Nigeria international journal of pure applied science technol., 15(2): 1-7.
- Arya, D.S., Taxak, A. K., and Murumkar, A.R. 2014. Long term spatial and temporal rainfall trends and homogeneity analysis in Wainganga basin, central India.
- Ashok, K. and Guan, Z. and Yamgata, T. 2004. "Impact of the Indian ocean dipole on the relationship between the Indian monsoon rainfall and ENSO." Institute for global change research.
- Chaudhary, J.I., Tomar, G.S. 1999. Agro climate analysis of stable rainfall periods in undivided Bastar district of Chhattisgarh region of Madhya Pradesh, India. *Oryza.*, 36(1): 66-69.
- Chhattisgarh- wikipedia, the free encyclopedia.
- Duhan D. and Pandey A. 2013. "Statistical analysis of long term spatial and temporal trends of precipitation during 1901–2002 at Madhya Pradesh, India," *atmospheric research*, vol. 122, pp.136–149.
- Hundal, S.S. and Kaur, P. 2002. Annual and seasonal climatic variability at different locations of Punjab state. *Journal of agrometeorology* 4(2):113-125.
- IPCC (1996) *The Science of Climate change*. Contribution of Working Group I to the second assessment report of the intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp:584.
- Jain, S. K. And Kumar, V. 2012. Trend analysis of rainfall and temperature data for India. *Current science Journal*, 102(1): 37-49.
- Jajoria, D. K., Sharma, S. K., Narolia, G. P. and Dotaniya, M. L. 2015. Rainfall variability a tool for crop planning of Udaipur region of India. *National academy science letter.*, 38(2): 95-98.
- Khavse R, Deshmukh R, Manikandan N. Chaudhary J.I, and Kaushik D. (2015). Statistical analysis of temperature and rainfall trend in Raipur district of Chhattisgarh during 1971-2013.
- Krishnakumar, K.N., Prasada Rao, G.S.L.H.V. and Gopakumar, C.S. 2009. Rainfall trends in twentieth century over Kerala, India. *Journals of atmospheric environment* 43: 1940-1944.
- Kumar, V., Jain, S. K. and Singh, Y. 2010. Analysis of long term rainfall trends in India, *Hydrological Sciences Journals*, 55:4, 484-496.
- Maragatham R. S., (2012) Trend analysis of rainfall data : a comparative study of existing methods. *International Journal of Physics and Mathematical Sciences*. 2:13-18.
- Meshram, S.G., Singh, V.P. and Meshram, C. 2016. Long-term trend and variability of precipitation in Chhattisgarh state, India. *Theoretical and applied climatology* ., 1:1-16.
- Mondal, A., Kundu, S., and Mukhopadhyay, A. 2016. Rainfall trend analysis by Mann-kendall test a case study of north-eastern part of Cuttack district,

Orissa, India. International journal of geology, earth and environmental sciences issn., 2(1): 70-78.

Parthasarathy, B. And Pant, G.B. (2006). "Seasonal relationships between indian summer monsoon rainfall an the southern oscillation." Journal of climatology. 5(4): 369-378.

Raipur- Wikipedia, the free encyclopedia.

Rasmusson, E. M. and Carpenter, T. H. 1982. "The relationship between eastern equatorial pacific sea surface and rainfall over india and srilanka."Monthly weather review. 111:517-528.

Reddy, R. D., Sreenivas, G., Mahadevappa, S. G., Madhavilata, A., Rao, S. B. N. andVama, N. R.G. 2007.Rainfall variability and its impact on agriculture north Telanganaregions of Andhra Pradesh.Journal of agromet. 9(2): 253-258.

Sheoran, P., Singh, S. P. and Sardana, V. 2008. Rainfall analysis and crop planning lower shiwalik foothills of Punjab. Journal of agrometeorology., 10(2): 193-197.

Yosef. Y. Saaroni. H. and Alpert, P.(2009) trends in daily rainfall intensity israel 1950/1-2003/4 the open atmospheric science journal. 3. 196-203.

Zhai P, Zhang X, Wan H and Pan X. 2005.trends in precipitation and frequency of daily precipitation extremes over china. J. Clim. 18: 1096-108

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