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Trends of rainfall in Parbhani region of Marathwada

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Abstract
Impact of global warming is not limited to global and regional changes in temperature; it also has significant impact on regional rainfall patterns, which may not only alter rainfall amount but rainfall distribution and patterns. Rainfall trend is an important tool which assesses the impact of climate change and provides direction to cope up with its adverse effects on the agriculture. This study focuses on rainfall variation and detecting trends in the annual, monthly, seasonal and weekly rainfall in Parbhani region of Marathwada in Maharashtra State. The analysis of rainfall variation was done by using statistical parametric test and trend analysis was done by using Mann-Kendall and Sen's slope test. The results revealed that, no trend was observed in annual, seasonal and monthly rainfall of Parbhani. Whereas increasing rainfall trend was observed in 23rd, 37th and 38th SMW at 95 and 90 per cent significance level respectively.

Keywords: Rainfall, trend, Mann-Kendall, Sen's slope, variability

1. Introduction
Indian agriculture is highly dependent on the spatial and temporal distribution of south-west monsoon rainfall (June-September). It is reported that a higher or lower or changes in the rainfall distribution would influence the spatial and temporal distribution of runoff, soil moisture, groundwater reserves and would alter the frequency of drought and floods. Analysis of rainfall trend is important in studying the impacts of climate change, water resources planning, drought, excessive rainfall and other environmental factors for the particular region. Trend analysis was carried out to study the long term trends in rainfall over disparate subdivisions. Precipitation trend analysis, on different temporal and spatial scales, has been of large concern during the past century because of the attention given to global climate change from the scientific community (IPCC, 1996) [16]. Various studies were carried out to find out the trend of rainfall (Easterling *et al.,* 2000; Francis and Gadgil, 2006; Guhathakurta and Rajeevan, 2006; Jain and Kumar, 2012; Pal *et al*., 2017; John and Brema 2018) [2, 3, 5, 7, 13, 8].

2. Materials and Methods
2.1 Study area description
The study area is situated at 19°16' N Latitude and 76°47' E Longitude; 409 meters above mean sea level (MSL) in division of Marathwada. It comes under moderate to moderately high rainfall zone with an average annual rainfall of 947.5 mm. The soil of the study area is medium deep black clay. (Tarate *et al.* 2017) [18].

2.2 Data collection
Daily rainfall data of 30 years from (1991 - 2020) were collected from Agricultural Meteorology Laboratory, Vasantrao Naik Marathawada Krishi Vidyapeeth, VNMKV, Parbhani, Maharashtra.

2.3 Software/Progremme
Microsoft office sub-module MS-Excel was used for data analysis. MAKESENS excel template was used for trend detection and estimation of magnitude of trend (Salmi *et al.* 2002) [16].

2.4 Statistical rainfall variation
2.4.1 Mean
Estimation of mean rainfall is required for determining the rainfall variation within the given period during a particular year. Mean is a measure of central tendency which is given as sum of all variables in series divided by number of variables. (Panse and Sukhatme, 1985) [14].

$$\overline{X} = \frac{\sum_{i=1}^{n} X_i}{N} \quad (1)$$

Where,
$\overline{X}$ = Mean,
X_i=Variable
N = Total number of variables

2.4.2 Standard deviation
It is a measure of variability or the scatter or the dispersion about the mean value. It is given by the following formula. (Robert *et al.* 1971) [15].

$$\sigma = \sqrt{\frac{\sum_{i=0}^{n}(X_i-\overline{X})^2}{N}} \quad (2)$$

Where
X_i = Variable
$\overline{X}$ = Mean
σ = Standard deviation
N = Total number of variables.

2.4.3 Coefficient of Variation
Coefficient of variation is a statistical measure of the dispersion of the data points in a data series around the mean. Coefficient of variation is defined as the standard deviation divided by the mean value of rainfall. (Robert *et al.* 1971) [15]. It shows the variability of rainfall in percentage

$$\text{CV (\%)} = \frac{\sigma}{\overline{X}} \times 100 \quad (3)$$

Where,
CV = Coefficient of variation
σ = Standard deviation and $\overline{X}$ = Mean

2.5 Rainfall trend analysis
Trend analysis of a time series consists of the magnitude of trend and its statistical significance. In this paper statistical significance trend analysis will be computed by using Mann-Kendall Test (Mann, 1945; Kendall, 1975) [12, 10] and magnitude of trend will be determined by non-parametric Sen's slope estimator method (Choudhury *et al*., 2012) [1].

2.5.1 Mann- Kendall method
This method is mostly used to check the null hypothesis of no trend versus alternate hypothesis of the existence of alternative monotonic increasing or decreasing trend. For time series less than 10 points S-Test can be used and for more than 10 data point's normal approximation (Z-Test) is used (Gilbert 1987).The Mann-Kendall Statistic (S) is given by following equation.

$$S = \sum_{k=1}^{n-1}\sum_{j=k+1}^{n} Sign\ (X_j - X_k) \quad (4)$$

Where,
X_j and X_k = Annual values in years j and k, j > k respectively
n = Number of observed data series
Sign ($X_j - X_k$) was calculated using equation,
Sign ($X_j - X_k$) was calculated using equation,

$$Sign(X_j - X_k) = \begin{cases} 1\ if\ (X_j - X_k) > 0 \\ 0\ if\ (X_j - X_k) = 0 \\ -1\ if\ (X_j - X_k) < 0 \end{cases} \quad (5)$$

$$\text{VAR(S)} = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p+1}^{q} t_p\,(t_p-1)\,(2t_p+5)\right] \quad (6)$$

Where,
n = Number of years
p = Number of tied group (a tied group is a set of sample data having the same value)
t_p= Number of data points in the tied group.

The standard normal distribution (Z- statistic) was computed by using equation,

$$Z = \begin{cases} \frac{S-1}{\sqrt{VAR(S)}}\ if\ S > 0 \\ 0\ if\ S > 0 \\ \frac{S+1}{\sqrt{VAR(S)}}\ if\ S > 0 \end{cases} \quad (7)$$

Positive or negative trends are determined at confidence levels of 99, 95 and 90 per cent. At the 99 per cent significance level, the null hypothesis of no trend is rejected if ∣Z∣ > 2.575; at the 95 per cent significance level null hypothesis of no trend is rejected at if ∣Z∣ > 1.96; and at the 90 per cent significance level, the null hypothesis of no trend is rejected if ∣Z∣ > 1.645.

2.5.2 Sen's slope method
Sen's estimator has been extensively used for determining the magnitude of trend in hydro- meteorological time series. The Sen's slope method can be used in cases where trend can be assumed as linear (Joshi *et al.* 2019) [9]. If a linear trend is present in a time series, then the true slope was estimated by using a simple non-parametric procedure developed by Sen (1968) [17]. This means that the linear model can be described as:

$$Q_t = \frac{X_i - X_k}{j-k} \text{ for I = 1, 2, 3………n} \quad (8)$$

Where, X_j and X_k = data values at time j and k, j > k.

$$Q_t = \begin{cases} Q_{\frac{N+1}{2}}\ if\ N\ is\ odd \\ \frac{1}{2}\left(Q_N + Q_{\frac{N+1}{2}}\right)\ if\ N\ is\ even \end{cases} \quad (9)$$

Median of all slope values gives Q, which is magnitude of trend. Positive value indicates increasing and negative values indicates decreasing trend of rainfall.

3. Results and Discussion
3.1 Annual variation and trend analysis of rainfall
Annual rainfall variations at Parbhani of 30 years are presented in Figure 1. It represents the annual rainfall for 30 years with maximum average annual rainfall of 1479.4 mm in the year of 1998 and minimum rainfall of 560.2 mm in the year of 1996. The mean, standard deviation was observed at study area 910.3 mm, 236.4 mm at 25.9 per cent coefficient of variation. Annual rainfall trend of Parbhani in over the 30 years didn't exhibit any statistical significant trend at the significance level of 90 per cent, 95 per cent and 99 per cent as presented in Table 1.

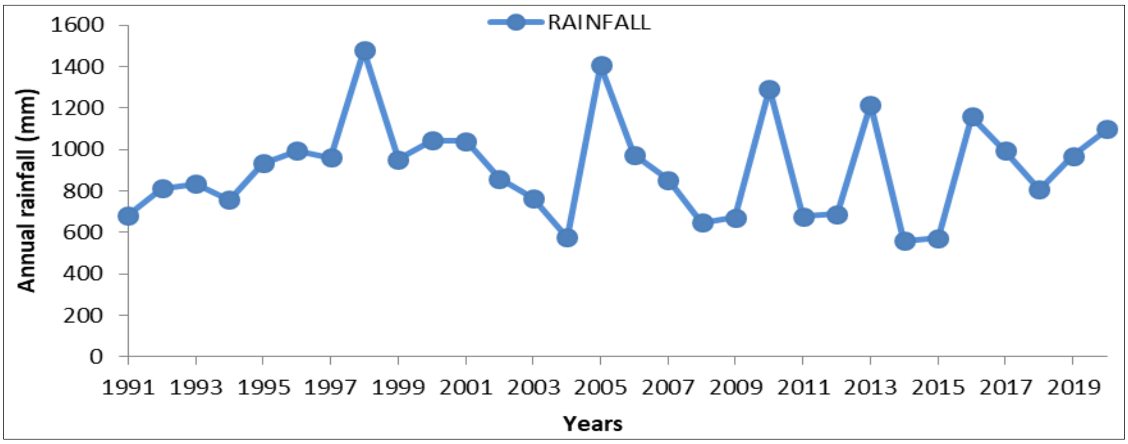

Fig 1: Annual rainfall variation at Parbhani of 30 years (1991-2020)

Table 1: Trend in annual rainfall and its magnitude

Time Series	First Year	Last Year	N	MK Test		SS Test	Trend
				Test Z	Significance	Q	
Annual	1991	2020	30	0.07		0.72	No

3.2 Seasonal rainfall trend analysis

Seasonal trend analysis was carried out considering four seasons in a calendar year *viz*., winter, summer, south-west and north-east by using Mann- Kendall and Sen's slope test. Results revealed that seasonal rainfall at Parbhani over the 30 years period did not show any statistical significant trend at significance level of 90 per cent, 95 per cent and 99 per cent as presented in Table 2.

Table 2: Trend in seasonal rainfall and its magnitude

Time Series	First Year	Last Year	N	MK Test		SS Test	Trend
				Test Z	Significance	Q	
Winter	1991	2020	30	-0.15		0.00	No
Summer	1991	2020	30	0.32		0.16	No
South-west	1991	2020	30	0.18		1.18	No
North-east	1991	2020	30	-0.29		-0.72	No

3.3 Monthly rainfall trend analysis

In the non parametric Mann-Kendall test, trend analysis of monthly rainfall was carried out for six months from May to October together with the Sen's magnitude of slope Q and the results are presented in Table 3. Results revealed that there was no trend observed in monthly rainfall of Parbhani.

Table 3: Trend in monthly rainfall and its magnitude

Time Series	First Year	Last Year	N	MK Test		SS Test	Trend
				Test Z	Significance	Q	
May	1991	2020	30	-1.55		-0.24	No
June	1991	2020	30	-0.36		-0.66	No
July	1991	2020	30	-0.32		-0.43	No
Aug	1991	2020	30	-0.11		-0.66	No
Sept	1991	2020	30	1.57		3.77	No
Oct	1991	2020	30	0.00		0.00	No

3.4 Weekly rainfall trend analysis

Results of weekly rainfall trend at Parbhani by using Mann-Kendall Test and Sen's slope estimation method are presented in Table 4. Results revealed that, there was no trend observed during standard meteorological week (SMW) 22nd, 24th to 36th and 39th to 43rd SMW because the values of Mann-Kendall Test Z are statistically non-significant. Whereas SMW 23rd, 37th and 38th showed increasing trend and the rate of increasing are 0.54 mm, 1.59 mm and 2.10 mm per week respectively. Increasing trend in 37th and 38th SMW exists at 95 per cent significance level whereas in 23rd SMW it exists at 90 per cent significance level.

Table 4: Trend in weekly rainfall and its magnitude

Time Series	First Year	Last Year	N	MK Test		SS Test	Trend
				Test Z	Significance	Q	
22	1991	2020	30	0.51		0.00	No
23	1991	2020	30	1.75	+	0.54	Increasing
24	1991	2020	30	-0.87		-0.73	No
25	1991	2020	30	-0.95		-0.84	No
26	1991	2020	30	0.12		0.13	No

27	1991	2020	30	0.29		0.05	No
28	1991	2020	30	0.18		0.11	No
29	1991	2020	30	0.18		0.03	No
30	1991	2020	30	0.36		0.23	No
31	1991	2020	30	-0.66		-0.36	No
32	1991	2020	30	-0.61		-0.17	No
33	1991	2020	30	0.20		0.16	No
34	1991	2020	30	-0.20		-0.17	No
35	1991	2020	30	-0.29		-0.17	No
36	1991	2020	30	-0.37		-0.32	No
37	1991	2020	30	2.14	*	1.59	Increasing
38	1991	2020	30	2.23	*	2.10	Increasing
39	1991	2020	30	0.09		0.00	No
40	1991	2020	30	1.37		0.20	No
41	1991	2020	30	0.30		0.00	No
42	1991	2020	30	-0.95		0.00	No
43	1991	2020	30	0.13		0.00	No

(* 95 per cent significance level if Z > ±1.96; + 90 per cent significance if Z > ±1.64)

4. Conclusion

The present study analyzed the rainfall data for 30 years from (1991 to 2020) of Parbhani for the determination of the rainfall trend. The results showed that, no trend was observed in annual, seasonal and monthly rainfall. Whereas increasing rainfall trend was observed in 23rd, 37th and 38th SMW at 95 and 90 per cent significance level respectively.

5. Acknowledgement

Daily rainfall data of 30 years from (1991 - 2020) were collected from Agricultural Meteorology Laboratory, Vasantrao Naik Marathawada Krishi Vidyapeeth, VNMKV, Parbhani, Maharashtra.

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