J. Agric. Res. Technol., 49 (3) : 421-425 (2024)

Rainfall Trend Analysis Using Mann-Kendall and Sen's Slope Test Method in Nanded District of Maharashtra State

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(Received : 01.06.2024 Accepted : 30.06.2024)

Abstract

Climate change is major concern globally particularly for rain fed developing countries, as shift in the amount and intensity of rainfall negatively impacts all sectors of these nations. The studywas carried out by using mann-kendall and sen's slope test method for tehsil wise annual average rainfall over Nanded district of Maharashtra state of India. The result revealed that the mean annual highest rainfall 1005.4 mm with a standard deviation 252.2 mm and coefficient of variation was 25.1% was recorded at Kinvat tehsil and the lowest mean annual rainfall recorded was 769.9 mm at Naigaon tehsilof Nanded district. Tehsil wise annual average rainfall trend showedArdhapur, Dharamabad, Himayatnagar, Loha, Mahur, Mudkhed, Naigaon and umari has rising trend and significant value. Biloli, Hadgaon, kandhar, Mukhed and nandedtaluka have rising trend with non-significant value. Bhokar, Degloor and Kinvat shows falling trend with non-significant value and the trend of any tehsil of Nanded is not falling and significant value.

Key words : Annual, Rainfall trend, Mann-kendall, Sen's slope, etc.

The primary physical environment component that supports economic development in each place is its climate, which also influences agriculture, industry, and all other economic development variables. It establishes how farmers' cropping patterns are distributed and performed. The hydrological cycle and the regional agricultural calendar may be significantly impacted by changes in rainfall patterns brought on by climate change (Mirza and Hussain 2003; Abrolet al., 2004; David Chikodzi and Linda YeukaiMapfaka, 2018). Rainfall is one of the decisive weather parameters for the detection of climate change (Sahu and Khare, 2015).Numerous scholars have examined the seasonal and annual patterns of rainfall in India on a regional level (Naidu et al., 1999; Guhathakurta and Rajeevan, 2008; Kumar et al., 2010; Gosainet al., 2011; Joshi and Pandey, 2011; Naveen Kumar et al. 2016). The majority of crops grown in the Marathwada region are rainfed, and crop productivity is contingent upon the amount and distribution of rainfall that occurs each month. Because of the sustainability of rainfed agriculture and the financial consequences of rainfall-dominated operations, it is crucial to have acute knowledge of both yearly and monthly rainfall and its pattern (Galkateet al., 1999). From the perspective of water management, recent trends in rainfall are more trustworthy since longer data sets also lessen the trend's relevance. In the twenty-first century, managing the region's crop water supplies effectively requires a spatial and temporal understanding of the rainfall that occurs there. In order to establish a connection between rainfall and other hydrological components, it is also necessary to detect patterns of rainy days in the area. This information can be useful in making decisions regarding the management of water resources as well as offering insights into potential changes in the hydrologic cycle of the area. The problem has gotten worse in recent years due to climate

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change, and it has been discovered that Maharashtra state, and the Marathwada region in particular, have recorded the greatest number of farmer suicides in 2014. By keeping this in view, present study was undertaken for trend analysis of the annual and monthly rainfall and rainy days in Marathwada region.

Study Area : Nanded is the second most populous city in Maharashtra's Marathwada division located on the bank of Godavari, having altitude 362 m above sea level.Nanded district has a physicalarea of 10,528 Sq. Km., which forms 3.41% of the total geographical area of Maharashtra State. The district of Nanded has between 18°15' and 19°55' North latitude and 77°7' to 78°15' east longitudes (Yannawaret al., 2013, Karnewar and Kadam, 2015).

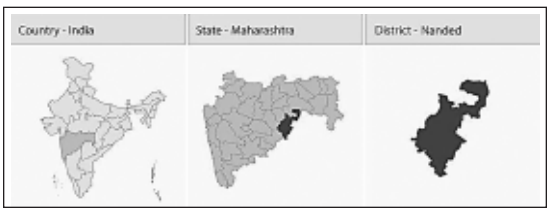

Fig. 1. Location map of study area

Data requirement : For the study of daily rainfall data of sixteen tehsils of Nanded district was collected for a period of 30 years i.e. from 1994 to 2023.

Sources of data : Rainfall data of all sixteen tehsils of Nanded district was collected from following websites.

(1) Department of Agricultural Meteorology, College of Agriculture, Parbhani

(2) State Agriculture Department, Pune

(3) India Meteorology Department, Pune

(4) Downloads from www.maharain.gov.in (www.krishi.maharashtra.gov.in)

(5) CHRS Data portal.

Methodology

Mann-Kendall Method : Compare first year data point with 2nd, 3rd, ...,30th year data point.

Assign,

+1 if X1 < X2-1

if X1 > X20

if X1 = X2

Sum of assigned values will give Mann-Kendall Statistic (S).

A very high value of Mann-Kendall statistic is an indicator of an increasing trend and a very low negative value indicated a decreasing trend. However, it is necessary to compute the probability associated with Mann-Kendall Statistic and the sample size, n, to statistically quantify the significance of the trend. The Mann-Kendall test statistic(S) is calculated using the formula that follows;

$$s = \sum_{k-1}^{n} . \sum_{j-k-1}^{n} sign(xj - xk) \quad (1)$$

Where, Xj and Xk are the annual values in years j and k, j > k respectively,

Xkre present the data point at time k.

The value of sign (xj - xk) is computed as number follows:

1 if xj-xk> 0

0ifxj -xk = 0

-1 if xj-xk< 0

This statistic represents the number of positive differences minus the number of negative differences for all the differences considered. For large samples (N>10), the test is conducted using a normal

approximation (Z statistics) with the mean and the variance as follows,

$$\text{Variance (S)} = \frac{(n-1)(2n+5)-\sum_{p=1}^{p=g}(tp-1)(2tp+5)}{18}$$

Where, n = number of years, g = number of tied groups, (A tied group is a set of sample data having the same value.) and tp = number of items in the tied group

Calculate a normalized test statistic Z by the following equation

$$Z = \frac{s+1}{\sqrt{variance(s)}} \quad \text{if } S > 0$$

$$Z = 0 \quad \text{if } S = 0$$

$$Z = \frac{s-1}{\sqrt{variance(s)}} \quad \text{if } S < 0$$

Where, S = p –q, p = number of (+1) values and q = number of (-1) values

The presence of a statistically significant trend is evaluated using the Z value. A positive value of Z indicates an upward trend and its negative value a downward trend. The statistic Z has a normal distribution. In the present study, at confidence level of 99, 95 and 90 per cent the positive or negative trends is determined by the test statistic.

Sen's Slope Method : Sen's slope method was used for predicting the magnitude of hydro meteorological time series data. This method uses a linear model for the trend analysis by using a simple nonparametric procedure developed by Sen (1968).

To derive an estimate of the slope Qt, the slope of all data pairs is calculated by

$$Qt = \frac{xj-xk}{j-k} \quad i = 1, 2, 3, N, J > k$$

Where, xj and xk is the data values for j and k times of a period and j>k

The slope is estimated for each observation. If there are 'n' values of Xj in the time series then as many as N = n(n-1)/2 slope estimates, Qt are to be computed. The Sen's estimator of slope is the median of these N values of Qt. The N values of Qt are ranked from the smallest to the largest and the Sen's estimator is calculated as,

$$\text{If N is odd} \quad \text{If N is Even} Qt = \begin{cases} Q\frac{N+1}{2} \\ \frac{1}{2}\left(Q\frac{N}{2} + Q\frac{N+2}{2}\right) \end{cases}$$

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

Result and discussions

Rainfall features : Taluka wise rainfall characteristics of Nanded district are shown in Table 1. Mean annual highest rainfall 1005.4 mm with a standard deviation 252.2 mm and

Table 1. Taluka wise annual mean of rainfall over Nanded district from 1994 to 2023

Tehsil	Mean (mm)	SD	CV (%)	COD	Contribution (%)
Nanded	776.6	284.1	36.6	0.051100	5.69
Biloli	786.1	247.4	31.5	0.030400	5.76
Mukhed	789.2	210.3	26.6	0.066900	5.79
Kandhar	798.7	254.9	31.9	0.001300	5.86
Loha	816.5	291.4	35.7	0.184200	5.99
Hadgaon	835.3	250.4	29.9	0.007900	6.12
Bhokar	942.5	280.6	29.8	0.000600	6.91
Degloor	808.3	267.5	33.1	0.016600	5.93
Kinvat	1005.4	252.2	25.1	0.000004	7.37
Mudkhed	865.5	320.8	37.1	0.291000	6.35
Himayatnagar	903.9	361.1	39.9	0.188000	6.63
Mahur	999.4	278.8	27.9	0.265000	7.33
Dharmabad	848.2	291.7	34.4	0.285000	6.22
Umari	822.6	247.2	30.1	0.256000	6.03
Ardhapur	871.5	301.8	34.6	0.540000	6.39
Naigaon	769.9	264.4	34.4	0.433000	5.64
Total Rainfall	13639.5				100

Table 2. Taluka wise annualrainfall Mann-Kendall's value of Nanded District

Annual	Kend-all's Tau	Statistics (s)	P value	Trend	TRND
Ardhapur	0.450	212	0.001	Rising	SIG
Bhokar	-0.051	-22	0.708	Falling	NS
Biloli	6.667	2.9	0.617	Rising	NS
Degloor	-0.080	-35	0.544	Falling	NS
Dharmabad	0.345	151	0.007	Rising	SIG
Hadgaon	1.613	7	0.915	Rising	NS
Himayatnagar	0.308	133	0.018	Rising	SIG
Kandhar	2.529	1.1	0.858	Rising	NS
Kinvat	-0.025	-11	0.858	Falling	NS
Loha	0.271	117	0.038	Rising	SIG
Mahur	0.269	116	0.040	Rising	SIG
Mudkhed	0.377	163	0.004	Rising	SIG
Mukhed	0.163	71	0.212	Rising	NS
Naigaon	0.472	199	0.001	Rising	SIG
Nanded	0.131	57	0.317	Rising	NS
Umari	0.049	111	0.049	Rising	SIG

TRND = Trend at 5% Significant level

Table 3. Annual taluka wise Sen's slope value of Nanded district

Annual	Sen's slope	Lower boundary	Upper boundary	Trend
Ardhapur	37.70	22.10	50.50	Rising
Bhokar	-1.69	-13.87	11.12	Falling
Biloli	3.30	-11.10	15.42	Rising
Degloor	-5.30	-20.45	8.42	Falling
Dharmabad	23.55	5.59	41.45	Rising
Hadgaon	0.36	-11.07	13.72	Rising
Himayatnagar	24.11	3.66	40.57	Rising
Kandhar	2.27	-12.08	12.63	Rising
Kinvat	-0.99	-11.70	12.84	Falling
Loha	19.56	0.08	33.35	Rising
Mahur	20.60	0.00	42.16	Rising
Mudkhed	26.52	9.25	42.73	Rising
Mukhed	7.17	-5.62	15.71	Rising
Naigaon	30.55	15.39	41.93	Rising
Nanded	6.25	-7.38	18.37	Rising
Umari	17.88	0.00	34.48	Rising

coefficient of variation is 25.1% was recorded at Kinvat tehsil of the Nanded district followed by Mahur at 999.4 mm. The lowest mean annual rainfall recorded was 769.9 mm at Naigaon tah.

In the non-parametric Mann-Kendall test, trend of annual rainfall for 30 years data from 1994-2023 at Nanded District has calculated annually and represented in (Table 2).

The Kendall's tau revealed that, Ardhapur, Dharamabad, Himayatnagar, Loha, Mahur, Mudkhed, Naigaon and umari has rising trend and significant value. Biloli, Hadgaon, kandhar, Mukhed and nanded taluka have rising trend with non-significant value. Bhokar, Degloor and Kinvat shows falling trend with non-significant value and the trend of any taluka of Nanded is not falling and significant value.

The Sen's slope test method analysis of annual rainfall represented in (Table 2) and revealed that Ardhapur, Biloli, Dharmabad, Hadgaon, Himayatnagar, Loha, Mahur, Mudkhed, Mukhed, Naigaon, Nanded and Umari show rising trend and remaining talukasBhokar, Degloor and Kinvat show falling trend annually.

Conclusions

Trend analysis was performed using the mann-kendall test and sen's slope estimator. Trend statistics indicate Ardhapur, Dharamabad, Himayatnagar, Loha, Mahur, Mudkhed, Naigaon and umari has rising trend and significant value. Biloli, Hadgaon, kandhar, Mukhed and nandedtaluka have rising trend with non-significant value. Bhokar, Degloor and Kinvat shows falling trend with non-significant value and the trend of any taluka of Nanded is not falling and significant value.

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