Trend Analysis of Annual Rainfall and Rainy Days Using Mann Kendall Method and Sen's Slope Estimator in Jalgaon District of Maharashtra

Kundan M. Kamble*, V.A. Sthool, S.K. Upadhye, J.D. Jadhav and S.V. Bagade

Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar, Maharashtra, India

*Corresponding author

A B S T R A C T

Rainfall occupies an important position in deciding the future planning of the cropping system in any rainfed agriculture. Indian agriculture is predominantly influenced by rainfall, specifically by the south-west monsoon (June–September). Rainfall trend is an important tool which assesses the impact of climate change and provides direction to cope up with its adverse effect on the agriculture. The Jalgaon district lies in the north-west side of Maharashtra and spreads across the Deccan Plateau in the rain shadow region of the Sahyadri mountain ranges on the northernmost tip of the state of Maharashtra. The present study entitled analysis of daily rainfall data of past years were used to compute annual rainfall and rainy days of fifteen tehsils of Jalgaon district using Mann Kendall method and Sen's slope estimator. Annual rainfall has been increased with increasing rainy days in Erandol and Yavaltehsils Rainfall in Jalgaon, Raver, Bodhwad, and Muktainagar tehsils decreased with decreasing rainy days and rainfall of Amalner, Bhadgaon, Jamner, Pachora and Dharangaon decreased with increasing rainy days.

Introduction

Agriculture plays an important role in the Indian economy which is located in southern Asia. As Indian agricultural country, small changes in the climatic condition largely affect the country's economy. The changes in the most important climatological parameter i.e. rainfall. Rainfall is the dominant single weather element influencing the intensity and location of the farming system and the choice of enterprise. India is highly influenced by the southwest monsoon. According to Guhathakurta and Rajeevan (2008), although average annual rainfall in the country is 119.4 cm, about 60 % of the country's total cultivable land remains as rainfed. The Maharashtra state is prominently agriculture-based. However, the share of the agriculture sector in the state's gross domestic production is less than 25%. The rainfall received in an area is an important factor in determining the

amount of water available to meet various demands, such as agricultural, industrial and domestic water supply. The Maharashtra state which is to the northwest of peninsular is facing water scarcity almost every year hence the trend analysis was carried out to examine the long term trends in rainfall over different subdivisions. The rainfall trend is very crucial for better economic development, hydrological planning and adaptation for extreme events.

Considering the above facts, present study is done to find out trends in annual rainfall and rainy days in fifteen tehsils of Jalgaon District.

Materials and Methods

Study area

The study area of this research is Jalgaon district lies in the north-west side of Maharashtra between 20º to 21° north latitude and 74º 55' to 76° 28' east longitude and spreads across the Deccan Plateau in the rain shadow region of the Sahyadri mountain ranges on the northernmost tip of the state of Maharashtra. The state of Madhya Pradesh lies to the north, the Buldhana district of Maharashtra to the east, the Aurangabad district of Maharashtra to south, Dhule and Nashik districts of Maharashtra to the west. To the north, we have the Satpura ranges and the river Aner goes from the northern part which forms the natural boundaries to the district. Tapiriver in the central part of the district also covers a large area with its tributaries which are the main river of the district. There are 15 tahasils in Jalgaon district viz., (1) Jalgaon (2) Jamner (3) Chalisgaon (4) Dhargaon (5) Bhusawal (6) Bodhwad (7) Yawal (8) Raver (9) Muktainagar (10) Amalner (11) Chopada (12) Pachora (13) Erandol (14) Bhadgaon and (15) Parola (Table 1).

Data collection

The daily rainfall data of all Tehsils in Jalgaon district are collected from (1) Department of Agricultural Meteorology, College of Agriculture, Pune (2) State Agriculture Department, Pune (3) India Meteorological Department, Pune and (4) Downloaded from www.maharain.gov.in (www.krishi.maharashtra.gov.in) from January to December.

Software used for study

Microsoft office sub-module MS-Excel was used for data analysis. The formulation and conditional statements were also executed in MS-Excel. The Weather Cock software developed by CRIDA, Hyderabad was used for the analysis of weather parameters, *viz.,* annual mean, standard deviation, coefficient of variation of rainfall and rainy days. MAKESEN'S excel template was used for trend detection and estimation of the magnitude of trend (Salmi *et al.,* 2002).

Rainfall and rainy days trend analysis

Trend analysis (increase or decrease) of all the independent weather parameters (*e.g.* annual rainfall and rainy days) was statistically examined by the non-parametric Mann-Kendall test and Sen's slope method (Choudhury *et al.,* 2012).

Mann-kendall test

Compare first-year data point with 2nd, 3rd,......, 58th-year data point.
Assign,
+1 if X1 < X2
-1 if X1 > X2
0 if X1 = X2

The 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 statistics is calculated using the formula,

$$S = \sum_{k-1}^{n} \sum_{j-k-1}^{n} \text{sign} (Xj - Xk) \ldots\ldots\ldots (4)$$

Where,
X_j and X_k are the annual values in years j and k, j > k respectively,
X_k represents the data point at time k.
The value of sign $(x_j$ _$x_k)$ is computed as the number follows:
1 if $x_j - x_k > 0$
0 if $x_j - x_k = 0$
-1 if $x_j - x_k < 0$

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:

Variance (S) =

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

Where,
n = number of years,
g = number of tied groups
(A tied group is a set of sample data having the same value.)
tp = number of items in the tied group
Calculate a normalized test statistic Z by the following equation,

$$Z = \frac{(S + 1)}{\sqrt{\text{Varience}(S)}} \quad \text{If} \quad S > 0$$

$$z = 0 \qquad\qquad \text{If} \quad S = 0$$

$$Z = \frac{(S - 1)}{\sqrt{\text{Varience}(S)}} \quad \text{If} \quad S < 0$$

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 a confidence level of 99, 95, and 90 per cent the positive or negative trends are 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 non-parametric procedure developed by Sen (1968).

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

$$Q_t = \frac{Xj - Xk}{j - k}, i = 1, 2, 3, N, j > k \quad \ldots (6)$$

Where,
x_j and x_k are 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 X_j in the time series then as many as N = n(n-1)/2 slope estimates, Q_t is to be computed. The Sen's estimator of the slope is the median of these N values of Q_t. The N values of Q_t are ranked from the smallest to the largest and the Sen's estimate is calculated as,

$$Q_t = \begin{cases} Q\frac{N+1}{2} & \text{If N is odd} \\ \frac{1}{2}(Q\frac{N}{2} + Q\frac{N+2}{2}) & \text{If N is even} \end{cases}$$

The median of all slope values gives Q, which is the magnitude of a trend. A positive value indicates increasing and negative values indicate a decreasing trend of rainfall and rainy days.

Results and Discussion

Trends in annual rainfall

The annual rainfall data for the period of 1961 to 2018 except Bodhwada, dharangaon and Muktainager tehsils from 1998 to 2018 is analysed using Mann Kendall test method and Sen's slope estimation method and results are given in table 2. Out of fifteen tehsils, the annual rainfall at Parola is increasing at 99 per cent significance level, Bodhwad and

Muktainagar are decreasing at 95 per cent significant level and Pachora is decreasing at 90 per cent of significance level. There was no significant trend observed in annual rainfall of remaining tehsils of Jalgaon district.

From table 2 it is also observed that the value of Mann Kendall test Z and Sen's slope estimate Q of 1) Amalner, Bhadgaon, Dhrangaon, Jalgaon, Jamner and Muktainagar is negative and 2) Bhusaval, Chalisgaon, Chopda and Erandol is positive. It indicates decreasing and increasing trend respectively even though it is statistically not significant (Fig. 1).

Trends in rainy days

Rainy days data shows that the trend in rainy days is increasing in Erandol tehsil at 95 per cent significance (Fig. 2).

Table.1 Geographical location and availability of data for study area

Sr. No.	Location of Raingauge Station	Geographical area (Km^2)	Latitude	Longitude	Period (year) From	To	No. of years
1)	Amalner	783.31	21 ° 05' N	75 ° 09' E	1961	2018	58
2)	Bhadgaon	443.07	21 ° 40' N	74 ° 05' E	1961	2018	58
3)	Bhusaval	440.05	21 ° 04' N	75 ° 45' E	1961	2018	58
4)	Bodhwad	372.31	20 ° 09' N	76 ° 01' E	1998	2018	21
5)	Chalisgaon	1192.33	20 ° 33 'N	75 ° 10' E	1961	2018	58
6)	Chopda	1147.58	21 ° 15'N	75 ° 18' E	1961	2018	58
7)	Dharangaon	497.21	21 ° 01' N	75 ° 16' E	1998	2018	21
8)	Erandol	509.99	20 ° 54' N	75 °23' E	1961	2018	58
9)	Jalgaon	11765.00	21 ° 00' N	75 ° 45' E	1961	2018	58
10)	Jamner	1308.94	20 ° 47 'N	75 ° 47' E	1961	2018	58
11)	Muktainager	497.21	21 ° 01' N	75 ° 16' E	1998	2018	21
12)	Pachora	807.74	20 ° 42 'N	75 ° 29' E	1961	2018	58
13)	Parola	780.00	20 ° 53' N	75 ° 07' E	1961	2018	58
14)	Raver	906.09	21 ° 15' N	7 ° 02' E	1961	2018	58
15)	Yaval	891.96	21 ° 10' N	75 ° 42' E	1961	2018	58

Table.2 Annual rainfall and rainy days trend analysis of all tehsils of Jalgaon District

Time series	First year	Last Year	N	Rainfall (mm)			Rainy days		
				Test Z	Signific.	Q	Test Z	Signific.	Q
Amalner	1961	2018	58	-1.13		-1.926	0.74		06
Bhadgaon	1961	2018	58	-0.95		-1.707	0.62		04
Bhusaval	1961	2018	58	09		0.12	0.74		06
Bodhwad	1998	2018	21	-1.96	*	-16.32	-1.24		-0.57
Chalisgaon	1961	2018	58	09		0.122	0.46		04
Chopda	1961	2018	58	0.87		1.622	-0.13		0
Dharangaon	1998	2018	21	-1.12		-11.12	-1.36		-0.63
Erandol	1961	2018	58	1.60		2.402	2.42	*	0.17
Jalgaon	1961	2018	58	-1.24		-1.903	-0.82		- 07
Jamner	1961	2018	58	-1.21		-2.70	0.05		0
Muktainagar	1998	2018	21	-2.33	*	-15.10	-0.15		0
Pachora	1961	2018	58	-1.79	+	-3.14	0.67		0.04
Parola	1961	2018	58	2.91	**	3.56	-0.28		0
Raver	1961	2018	58	-1.52		-2.74	-1.44		-0.13
Yaval	1961	2018	58	1.01		1.812	0.69		0.05

* Significance at 95 per cent confidence level, ** Significance at a 99 per cent confidence level and
\+ Significance at 90per cent confidence level

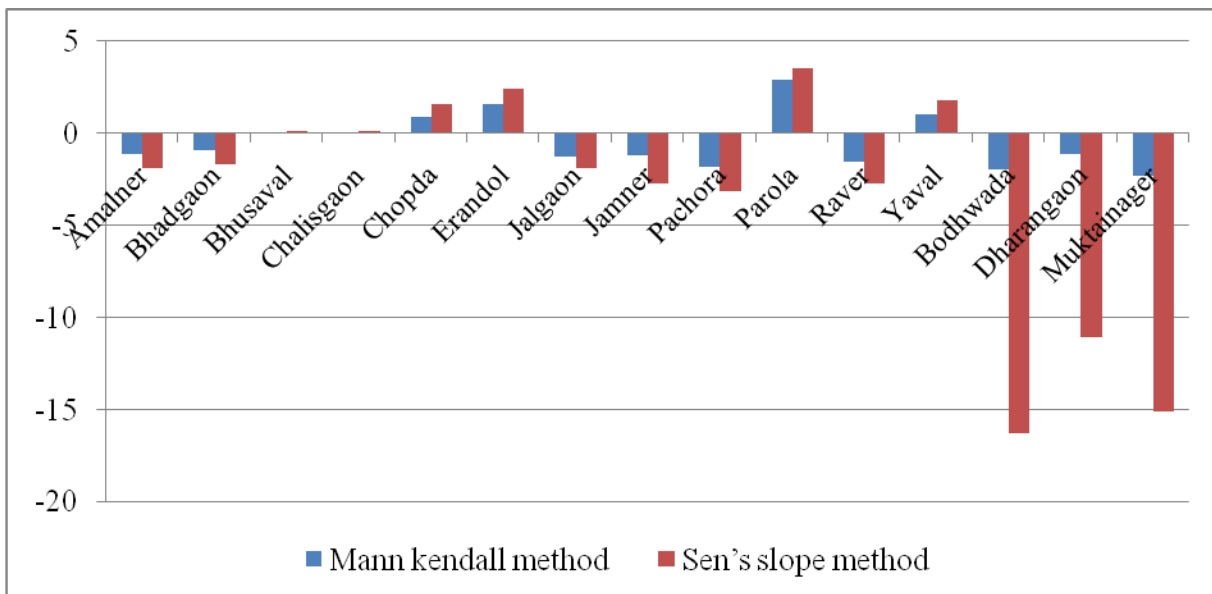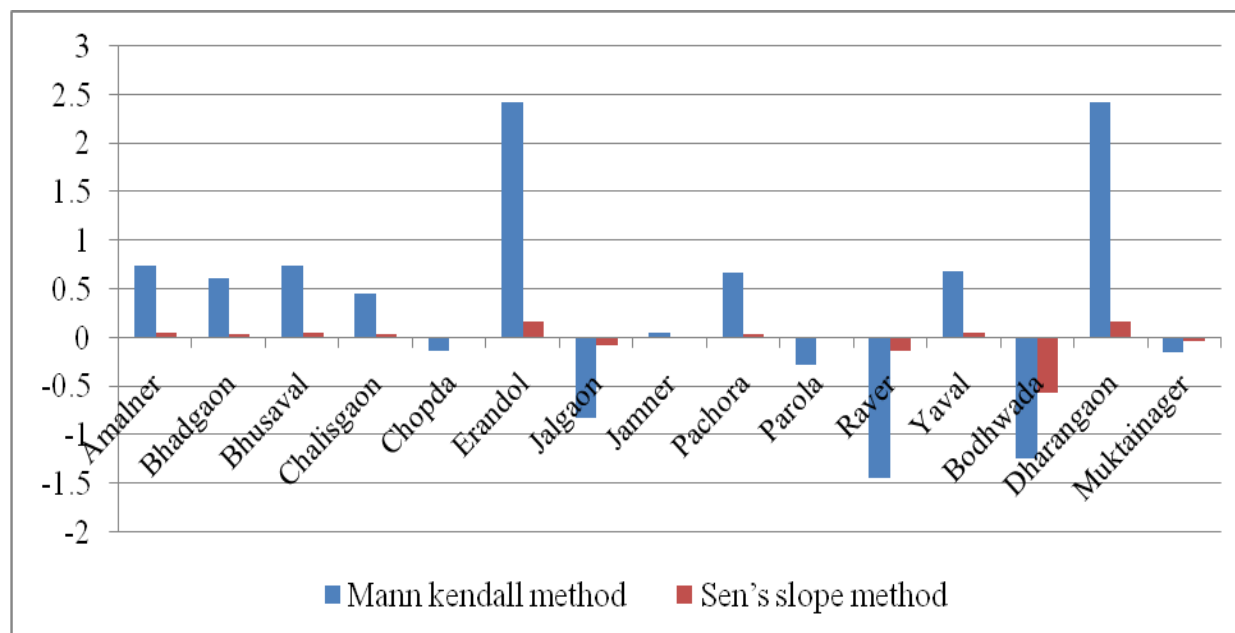**Fig.1** Method wise analysis of annual rainfall trend

Fig.2 Method wise analysis of annual rainy days trend

From the table 2 it is also observed that the value of Mann Kendall test Z and Sen's slope estimate Q for rainy days of Amalner, Bhadgaon, Bhusaval, Chalisgaon, Pachora and Yavalare positive it indicates increasing trend in rainy days even though it is statistically not significant. The value of Mann Kendall test Z and Sen's slope estimate Q for rainy days of Bodhwad, Dharangaon, Jalgaon and Raver are negative. It indicates decreasing trend in rainy days even though it is statisticaly not significant.

There was no trend observed in Chopda, Jamner, Muktainagar and Parola

Hence concluded, by using the Mann Kendall test and Sen's slope method trend in rainfall and rainy days were determined which is useful for determining the increasing or decreasing trends and it's magnitude in annual rainfall and rainy days. Annual rainfall has been increased with increasing rainy days inErandol and Yaval tehsils Rainfall in Jalgaon, Raver, Bodhwad, and Muktainagar tehsils decreased with decreasing rainy days

and rainfall of Amalner, Bhadgaon, Jamner, Pachora and Dharangaon decreased with increasing rainy days.

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Study area

Jalgaon district of Maharashtra, India

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