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Analysis of annual rainfall and rainy days trend using Mann Kendall method and sen's slope estimator in Sangli District of Maharashtra

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Abstract
Analysis of rainfall trends is important in studying the impacts of climate change, water resources planning, drought, excessive rainfall and other environmental factors for the particular region. The failure of monsoon has had a disastrous effect on the agriculture sector and a large share of the population dependent on agricultural for livelihood. Sangli district is situated in Western Maharashtra scarcity and Western Maharashtra plain, agro climatic zone of Maharashtra. The present study entitled analysis of annual rainfall and rainy days trend in nine tahsils in Sangli district of Maharashtra state using mann kendall method and sen's slope slope method. The results showed that the Atpadi, Kavthemahankal, Miraj and Palus tahsils showed increasing rainfall and rainy days trend while Jat, Tasgaon and Khanapur tahsils showed decreasing rainfall and rainy days trend. Shirala tahsil showed decreasing rainfall trend and Walwa tahsil showed decreasing rainfall trend with increasing rainy days trends.

Keywords: Rainfall trend, Rainy days trend, Mann Kendall method, Sen's slope method, Sangli

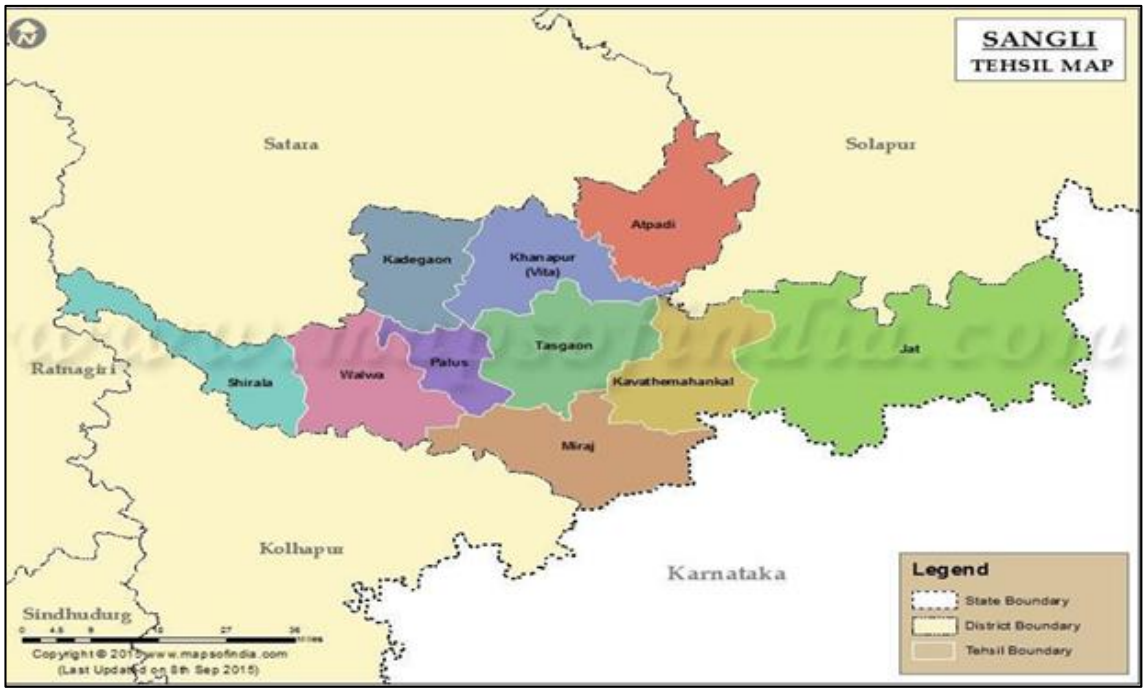
1. Introduction
The rainfall is an important factor for determining the availability of water for agriculture and other usages. The more accurate information about meteorological parameters and their trends are needed for the formulation of weather model, which will help to improve sustainability of water resource management planning. Rainfall pattern and the quantity decide the cropping system in the rainfed agriculture. Rainfall amount, distribution and intensity of rainfall mainly determine the choice of any particular crop and agronomic practices. Analysis of rainfall would enhance the management of water resources applications as well as the effective utilization of water resources. This trend analysis helps in water resource management through appropriate measures and formulation of adaptation measures through appropriate strategies.
Sangli district is a district of Maharashtra State in West-Central India. The climate of Sangli district is generally hot and dry. The average annual rainfall of Sangli district is 603 mm with 41 rainy days. The average annual rainfalls ranged from 367 mm at Palus with 33 annual rainy days to 1079 mm at Shirala with 66 rainy days (Wale, 2019) [18]. June to September is the months of normal rainy season. The amount of rainfall received over in district is an important factor in assessing the amount of water available to meet the various demands of agriculture, irrigation and other human activities. The rainfall in the western part of the district near the Western Ghats is higher than in the rest of the district and eastern tahsils are always drought prone. The district receives rain from the south-west as well as north-east monsoons. The rainfall in the western part of the district near the Western Ghats is higher than in the rest of the district. The rainfall is comparatively less as we go from the Western Ghats to the Eastern part of the district. The Shirala tahsil which is near the western border of the district gets about 1078.9 mm and Atpadi in the eastern part gets only average rainfall of about 396.2 mm. Sometimes rainfall in the form of thunder showers occurs in May. But the main rainy season is from June to September. The Walwa, Miraj, Tasgaon and Khanapur tahsils have the average rainfall of about 546 mm to 733 mm in the year. As such the eastern tahsils are always the drought prone. One-third of the district receives assured rainfall, while the rest has to face the vagaries of the monsoon (Anonymous, 2013) [1]. Sangli district contribute to 2.5 per cent of state geographical area (7.76 Lakh ha), gross cropped area and net cropped area was 6.49 Lakh ha and 5.57 Lakh ha (Anonymous, 2015) [2].
Various studies were carried out to determine the trend of rainfall (Gedefaw, M. *et al*., 2018; John and Brema 2018; Pal *et al.*, 2017; Easterling *et al.*, 2000; Francis and Gadgil, 2006; Griffiths *et al*., 2003; Guhathakurta and Rajeevan, 2006; Haylock, 2006, Jain and Kumar, 2012 and Kunkel, 2003) [5, 11, 15, 3, 4, 7, 8, 9, 10, 13].

Many methods, parametric and nonparametric, have been applied for determining the trends. Mann Kendall test (Mann, 1945 and Kendall, 1975) [14, 12] is one of the commonly used non-parametric tests for determining a trend in hydrologic time series, whereas many methods also used for analysis of trend. The advantage with a nonparametric test is that it only requires data to be independent and can tolerate outliers in the data.

Trend defined as long-term change in the mean level, but there is no fully satisfactory mathematical definition. However, trend analysis helps in forecasting. Trend is present when a time series exhibits steady upward growth or a downward decline, at least over successive time periods. The major challenge today is to formulate and implement a rational methodology for managing the available water resources in the areas. In this context expecting amount of rainfall for the crop period is very important factor in water management. Therefore, determination and identification of trends of precipitation is a key. So, the trend analysis of rainfall and rainy days will be useful to construct the future scenario of water availability and useful for forecasting the future temporal and spatial availability of water.

2. Materials and Methodology

2.1 Study area



The study area of this research is the Sangli district in state of Maharashtra in west-central India. It comprises of 10 districts *i.e.* Atpadi, Kavthemahankal, Miraj, Jat, Shirala, Tasgaon, Kadegaon, Walwa, Khanapur and Palus. It is situated between the 16°5' North and 17°33' North latitude and 73°41' East to 75°41' East longitudinal. The district is situated at an average height of about 553 m above the mean sea level. The average length of the Sangli district is 126 km and it spread into East Jat tahsil to west Shirala tahsil and roughly, squarish width 122 km is spread between Miraj tahsil in the South to Atpadi tahsil in the North. The total geographical area of the district is 8578 km^2. The average annual rainfall of Sangli district is 603 mm. It is bounded by Satara and Solapur district to the North, Bijapur district to the East, Kolhapur district to the South, and Ratnagiri district to the West.

2.3 Data collection

Daily rainfall data is collected from Department of Agricultural Meteorology, College of Agriculture, Pune, Downloaded from www.maharain.gov.in (www.krishi.maharashtra.gov.in) from the month of January to December and India Meteorological Department, Pune.

2.4 Software/Programme

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].

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

Sr. No.	Name of tehsil	Latitude	Longitude	Period (year)		Number of years
				From	To	
1	Atpadi	17.420°N	74.937°E	1982	2018	37
2	Kavthemahankal	17.945°N	73.976°E	1982	2018	37
3	Miraj	16.850°N	74.610°E	1982	2018	37
4	Jat	17.059°N	75.212°E	1961	2018	58
5	Shirala	17.015°N	74.116°E	1961	2018	58
6	Tasgaon	17.033°N	74.599°E	1961	2018	58
7	Walwa	16.494°N	74.230°E	1988	2018	31
8	Khanapur	17.264°N	74.708°E	1998	2018	21
9	Palus	17.091°N	74.458°E	1998	2018	21

2.5 Rainfall and rainy days trend analysis

Trend analysis (increase or decrease) of annual rainfall and rainy days was statistically examined by the non-parametric Mann-Kendall method and Sen's slope method.

2.6 Mann Kendall method

The Mann-Kendall test statistic (S) is calculated using the formula that follows (Mann, 1945) [14];

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

Where, X_j and X_k are the annual values in year's j and k, j > k respectively and X_k represent the data point at time k.
The value of sign (x_j - x_k) is computed as number follows

$$\text{Sign} = \begin{cases} +1 & if \quad xj - xk > 0 \\ 0 & if \quad xj - xk = 0 \\ -1 & if \quad xj - xk < 0 \end{cases}$$

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:

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

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

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

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

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

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

2.7 Sen's slope method

Sen's slope method has been 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 was calculated;

$$Q_t = \frac{Xj - Xk}{j-k}, \; i = 1, 2, 3, N, \; j > k$$

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 are to be computed. The Sen's estimator of slope is the median of these N values of Q_t. The N values of Q_t were ranked from the smallest to the largest and the sen's estimate was calculated as;

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

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.

3. Result and Discussion

The Mann Kendall trend, its statistical significance along with magnitude of Sen's slope for rainfall and rainy days data is shown in Table 2. The Mann Kendall method results showed that annual rainfall and annual rainy days of Atpadi, Miraj, Shirala and Palus tahsils didn't exhibit any statistical significant trend at the significance level of 90 per cent, 95 per cent and 99 per cent. Sen's slope method showed increasing trend of annual rainfall and annual rainy days. The Z statistics showed nature of annual rainfall trends at Atpadi (Z=0.48), Miraj (Z=0.72) and Palus (Z=1.30) tahsils were increasing. The Z statistics showed nature of annual rainy days trends at Atpadi (Z=1.02), Miraj (Z=1.43) and Palus (Z=0.36) tahsils were increasing. The Z statistics showed nature of annual rainfall trends at Shirala tahsil (-1.01) was decreasing.

Table 2: Trend analysis of annual rainfall and rainy days for study tahsils of Sangli of Maharashtra state using Mann kendall method and Sen's slope method

Tahsil	First year	Last Year	Rainfall (mm)			Rainy days		
			Test Z	Signific.	Q	Test Z	Signific.	Q
Atpadi	1982	2018	0.48	-	1.632	1.02	-	0.132
Kavthemahankal	1982	2018	2.52	*	6.850	2.81	**	0.500
Miraj	1982	2018	0.72	-	2.235	1.43	-	0.234
Jat	1961	2018	-1.78	+	-3.361	-1.45	-	-0.114
Shirala	1961	2018	-1.01	-	-1.833	0	-	0
Tasgaon	1961	2018	-3.38	**	-5.038	-3.26	**	-0.250
Walwa	1988	2018	-2.55	*	-10.918	0.19	-	0.037
Khanapur	1998	2018	-1.96	*	-17.844	-0.30	-	-0.063
Palus	1998	2018	1.30	-	7.350	0.36	-	0.254

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

The Mann Kendall method results showed that annual rainfall for Kavthemahankal tahsil was significantly increasing (Z=2.52) at the significance level of 95 per cent and annual rainy days was significantly increasing (Z=2.81) at the significance level of 99 per cent, For Jat tahsil, annual rainfall trend was significantly decreasing (Z=-1.78) at the significance level of 90 per cent and annual rainy days trend didn't exhibit any statistical significant trend at the significance level of 90 per cent, 95 per cent and 99 per cet and For Tasgaon tahsil, annual rainfall (Z=-3.38) and rainy

days (Z=-3.26) trend was significantly decreasing at the significance level of 99 per cent.

The Mann Kendall method results showed decreasing annual rainfall trend for Walwa tahsil (Z=-2.55) and for Khanapur tahsil (Z=-1.96) at the significance level of 95 per cent. The annual rainy days of Walwa tahsil and Khanapur tahsil didn't exhibit any statistical significant trend at the significance level of 90 per cent, 95 per cent and 99 per cent. The highest increasing annual rainfall and rainy days trend at Kavthemahankal followed by Palus, Miraj and Atpadi tahsils while, decreasing rainfall and rainy days trend at Jat, Tasgaon and Khanapur tahsils. The Walwa tahsil showed decreasing rainfall trend but increasing rainy days.

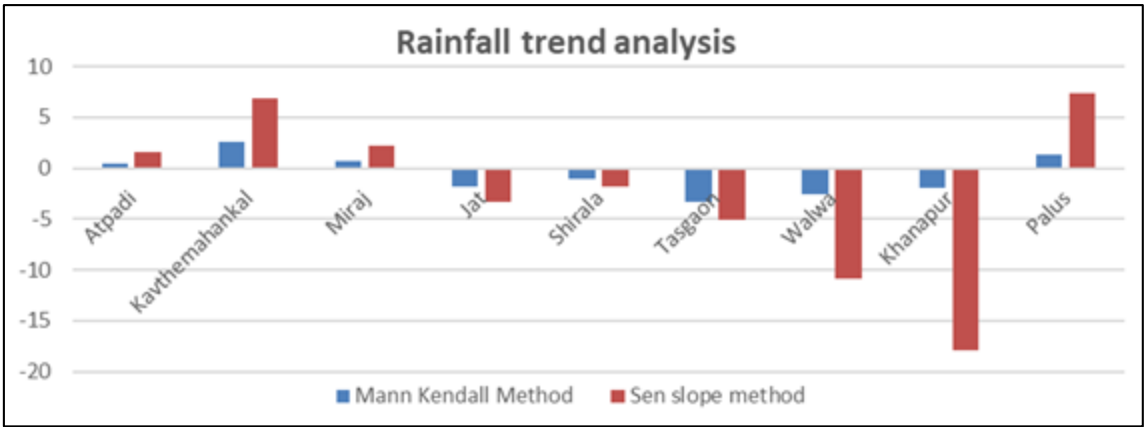


Fig 1: Method wise analysis of annual rainfall trend

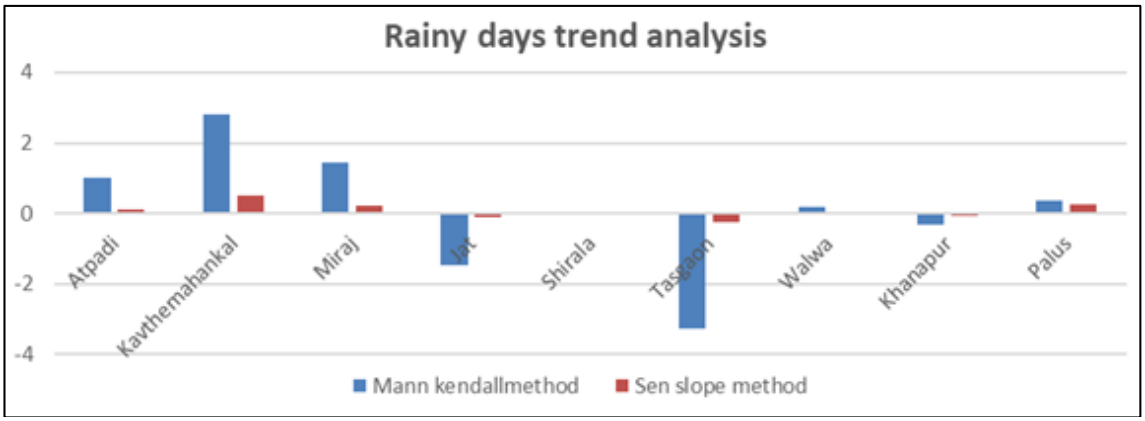


Fig 2: Method wise analysis of annual rainy days trend

4. Conclusions

The annual rainfall in Atpadi, Kavthemahankal, Miraj and Palus tahsils increased with increased in rainy days, the annual rainfall in Jat, Tasgaon and Khanapur tahsils decreased with decreased in rainy days and the annual rainfall of Walwa tahsil decreased with increased in rainy days.

Application of Research: To study the impacts of climate change, drought conditions, extreme rainfall events, annual trend in rainfall and rainy days for Sangli district of Maharashtra, India.

Research category: Quantitative research

Abbreviation: MH: Maharashtra; Km: Kilometre; Km^2: Kilometre square; ^oN: Degree North, ^oE: Degree East; IMD: India Meteorological Department; No: Number; mm: Millimetre; and ha: Hector.

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Study area: Sangli district of Maharashtra, India

Conflict of Interest: None declared

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