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Analysis of rainfall and rainy days trend in Shirala Tahsil of Sangli district of Maharashtra (India)

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Abstract
The daily rainfall data of fifty eight years (1961-2018) for Shirala tahsil has been analysed to determined the trend in rainfall and rainy days on annual, seasonal and monthly basis using mann kendall test, its statistical significance along with magnitude of sen's slope methods. The trend was calculated individually for each season and each month (May to November) for 58 years. The mann kendall test showed that annual rainfall and rainy days of Shirala tahsil didn't exhibit any statistical significant trend and sen's slope method showed decreasing trend of annual rainfall. The rainfall and rainy days trend were significant decreasing, for summer and north east monsoon season. The rainfall trend was significant decreasing, for the month of May and November, the rainy days trend was significant increasing for June and decreasing for May and November.

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

Introduction
Quantitative estimation of the spatial distribution of rainfall and rainy days is required for various purposes like water resource management, hydrological modeling, flood forecasting, climate change studies, water balance computations, soil moisture modeling for crop production, irrigation scheduling etc.

The rainfall and rainy days trend analysis study helps to assess the monsoon pattern of the region so as to predict chances of occurrence of flood, drought and determining the amount of water available to meet various demands, such as agricultural, industrial and domestic water supply. In India rainfall plays a major role in determining the economy of the country and knowledge regarding its trends helps us in the economic development, disaster management, hydrological planning of the country.

Sangli district is located in the western part of Maharashtra. It is situated between the 16°5'N to 17°33'N latitude and 73°41'E to 75°41'E longitudinal. The climate of Sangli district is generally hot and dry. The average annual rainfall of Sangli district is 603 mm with 41 rainy days (Wale, 2019) [18]. The district receives rain from the south-west as well as north-east monsoons. June to September is the months of normal rainy season.

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]. One-third of the district receives assured rainfall, while the rest has to face the vagaries of the monsoon. (Anonymous, 2013) [1].

Trend analysis helps to indicate whether the climate parameters are increasing or decreasing over time. In addition, an estimate of the trend's magnitude can help to determine whether a statistically significant trend over a period of time is present or not.

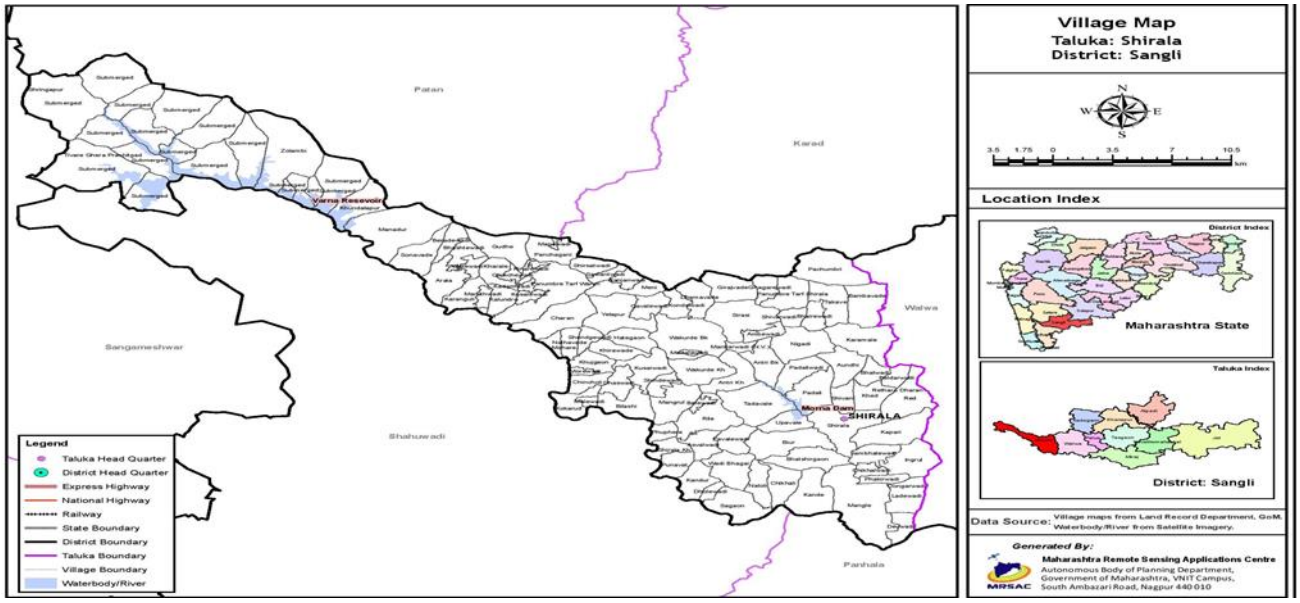
It is a key for predicting the rainfall and rainy days of a particular place on the basis of yearly, monthly rainfall and rainy days data for planning of the agricultural activities of the area. Various studies were carried out to determine the trend of rainfall. (Gedefaw, M. *et al*., 2018; John and 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, 6, 7, 8, 10, 13].

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. The advantage with a nonparametric test is that it only requires data to be independent and can tolerate outliers in the data.

Materials and Methodology

Study area

Shirala is the most important tahsil of Sangli district located in western Maharashtra. Itis situated between the 16.984°N latitude and 74.124°E longitudinal. It is situated at an average height of about 594 m above the mean sea level. The average annual rainfall of Shirala tahsil is 1078.90 mm and 66 average rainy days. The major source of income for people is from agriculture. A couple of agriculture-based industries (sugar and starch) also contribute to the economy. Water supply for drinking and agricultural purposes is available from Morna Dam. The tehsil has large area under thick forests due to heavy monsoon rains. It provide patronage to variety of wild life in 'Chandoli abhay-aranya', a national forest.



(https://mrsac.gov.in.)

Data collection

Daily rainfall data were collected from Department of Agricultural Meteorology, College of Agriculture, Pune, India Meteorological Department, Pune and Downloaded from www.maharain.gov.in (www.krishi.maharashtra.gov.in) from the month of January to December for the period fifty eight years from 1961 to 2018.

Software/Programme

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

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.

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

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

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

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

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 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) [17].

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.

Result and Discussion

The Mann Kendall trend, its statistical significance along with magnitude of Sen's slope for 1961 to 2018 year rainfall and rainy days data is shown in Table 3.1.

Annual rainfall and rainy days trend analysis

The test results showed that annual rainfall and rainy days of Shirala tahsil over the 58 years 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 decreasing trend of annual rainfall.

Table 1: Rainfall and rainy days trend analysis at Shirala tehsil

Time series		Rainfall (mm)			Rainy days		
		Test Z	Signific.	Q	Test Z	Signific.	Q
Annual		-1. 01	-	-1. 833	0	-	0
Seasonal	Winter	0.39	-	0	0.42	-	0
	Summer	-3.14	**	-1. 588	-3.11	**	-0.077
	SW	0.40	-	1.071	1.36	-	0.150
	NE	-1.87	+	-1.284	-1.71	+	-0.048
Monthly	May	-2. 75	**	-0. 833	-2. 36	*	-0. 038
	June	0.82	-	*0.855*	*1.70*	+	0.077
	July	-0.13	-	-0.267	0.76	-	0.027
	August	0.64	-	0.545	-0.16	-	0
	September	0.86	-	0.460	0.83	-	0.019
	October	-0.60	-	-0.143	0.15	-	0
	November	-2.11	*	-0.017	-2.75	**	0

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

Seasonal rainfall and rainy days trend analysis: The rainfall trend was significant decreasing, for summer (Z=-3.14) at 95 per cent confidence level and north east monsoon (Z=-1.87) at 90 per cent confidence level. The rainy days trend was significant decreasing, for the summer (Z=-3.11) at 99 per cent confidence level and for the north east monsoon (Z=-1.71) at 90 per cent confidence level. The Q statistics showed nature of rainfall trends and rainy days trend at Shirala tahsil during summer and north east monsoon were significantly decreasing.

Monthly rainfall and rainy days trend analysis: The rainfall trend was significant decreasing, for May (Z=-2.75) and November (Z=-2.11) at 99 per cent level of significance and 95 per cent level of significance, respectively. The Q statistics showed nature of annual rainfall trends at Shiral tahsil during May and November were significantly decreasing. The rainy days trend was significant increasing, for June (Z=1.70) and decreasing for May (Z=-2.36) and November (Z=-2.75) at 90 per cent, 95 per cent and 99 per cent confidence level, respectively.

The Q statistics showed nature of rainy days trends at Shirala tahsil during May and November were significantly decreasing while during June was significantly increasing.

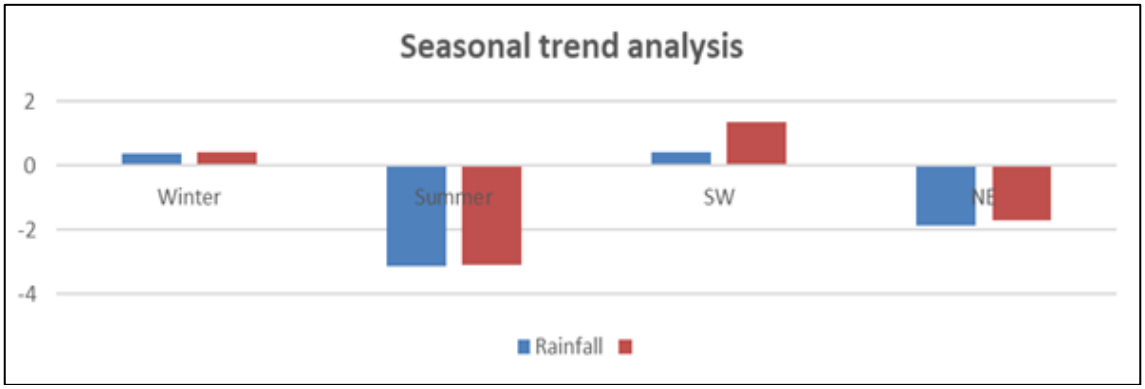


Fig 1: Seasonal trend in rainfall and rainy days

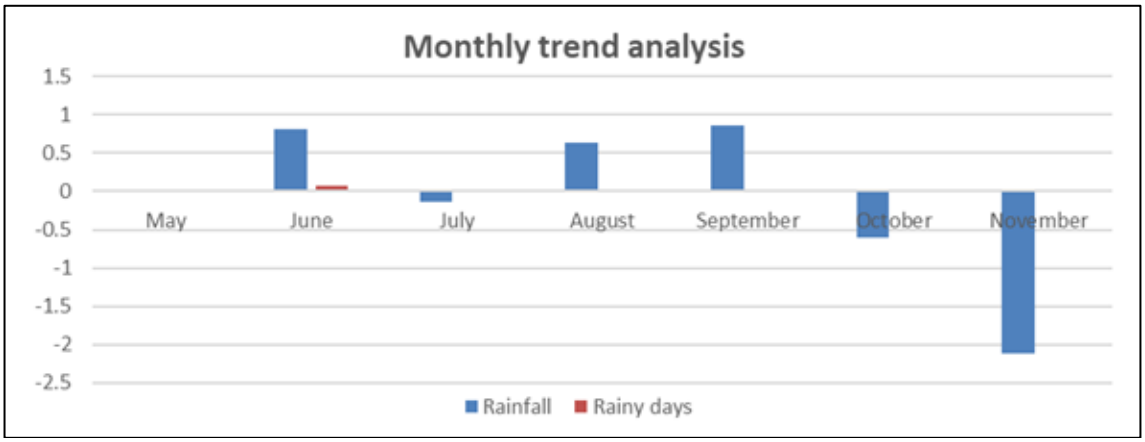


Fig 2: Monthly trend in rainfall and rainy days

Conclusions

The annual rainfall and rainy days data showed decreasing trend for Shirala tahsil. The seasonal rainfall and rainy days showed increasing trend for winter and southwest monsoon season while decreasing trend for summer and northeast monsoon season. The monthly rainfall and rainy days trend were increased for June and September while decreased for May and November. The monthly rainfall trend for July and October were decreased but increased in rainy days. The monthly rainfall trend for August was increased but decreased in rainy days.

Abbreviations

Km: Kilometre; Km^2: Kilometre square; ^oN: Degree North, ^oE: Degree East; IMD: India Meteorological Department; No.: Number; mm: Millimetre; Signific.: Significant; *et al.*: and others; SW: southwest; NE: Northeast and ha: Hector.

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