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Trend analysis of rainfall and rainy days using Mann Kendall method and sen's slope estimator in Tasgaon Tahsil of Sangli District of Maharashtra (India)

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Abstract
The study has been carried out to investigate and assess the significance of the potential trend of rainfall and rainy days over the Tasgaon tahsil of Sangli district of Maharashtra. In this study, trend analysis has been carried out on annual, seasonal and monthly basis using the data period between 1961 to 2018 for rainfall and rainy days. Mann-Kendall test and Sen's slope estimate test were applied to identify the existing trend direction and Sen's slope estimator test were used to detect the trend direction and magnitude of change over time. The test results showed decreasing rainfall and rainy days trend over the Tasgaon tahsil for annual, seasonal and monthly (May to November) time series.

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

1. Introduction
Precipitation is the key climatic variable that affect both the spatial and temporal patterns of water resources (Girma *et al.* 2016) [7]. Analyzing the long-term trends and variability of rainfall is very important for sustainable water resources management (Yang *et al.* 2017) [22]. Rainfall pattern and the quantity decide the cropping system, 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. Trend analysis of rainfall is also essential to study the impacts of climate change for water resources planning and management (Duhan and Pandey, 2013) [3].

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) [21]. 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) [1]. One-third of the district receives assured rainfall, while the rest has to face the vagaries of the monsoon. (Anonymous, 2013) [2].

There are various methods used to identify hydrometeorological time series (Duhan and Pandey, 2013) [3]. Trend analysis of rainfall time series includes determination of increasing and decreasing trend and magnitude of trend andits statistical significance (Jain and Kumar, 2012) [12] by using parametric and non-parametric statistical methods. Mann-Kendall test (Mann, 1945 and Kendall, 1975) [17, 14] is one of the best methods amongst them, which is preferred by various researchers (Jain and Kumar, 2012) [12]. 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 and Kunkel, 2003) [6, 13, 18, 4, 5, 9, 10, 11, 15].

The rainfall and rainy days trend is very crucial for the economic development and hydrological planning for the country. 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. 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

Tasgaon is the most important tahsil of Sangli district of Maharashtra. It is situated between the 17.033°N latitude and 74.599°E longitudinal. It is situated at an average height of about 560 meters above the mean sea level. The total geographical area of the tahsil is 968.29 km^2. (District Socio-economic Statistical Abstract, 2011) [8]. The average annual rainfall of Tasgaon tahsil is 624.30 mm and 45 average rainy days. The major source of income for people is from agriculture. Tasgaon is one of the famous places in Maharashtra for grapes. Farmers develop many types of grapes bagicha (vineyards). In Tasgaon tahsil, Lokarewadi village is famous for quality grapes, Kaulage and Lodhe Lake are known for sugarcane and grapes production, Manjarde, Balgavde and Bastawde are know for the production of sugarcane and Siddhewadi is famous for "lake" water used for irrigation and drinking.

2.2 Data sources

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.

2.3 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) [19].

2.4 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.

2.5 Mann Kendall method

The Mann-Kendall test statistic(S) is calculated using the formula that follows (Mann, 1945) [17];

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

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

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

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 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.

2.6 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) [20].
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 1961 to 2018 year rainfall and rainy days data is shown in Table 3.1.

3.1 Annual rainfall and rainy days trend analysis: The test results showed that annual rainfall (Z= -3.38) and rainy days (Z= -3.26) were significantly decreasing at the significance level of 99 per cent over 58 years. The Q statistics showed nature of annual rainfall and rainy days trends at Tasgaon tahsil were significantly decreasing.

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

Time series		Rainfall (mm)			Rainy Days		
		Test Z	Signific.	Q	Test Z	Signific.	Q
Annual		-3. 38	**	-5. 038	-3. 26	**	-0. 250
Seasonal	Winter	-0.35	-	0	-0.56	-	0
	Summer	-3.82	**	-1.400	-4.19	**	-0.098
	SW	-1.68	+	-2.125	-1.25	-	-0.083
	NE	-2.43	*	-1.300	-2.25	*	-0.063
Monthly	May	-2.46	*	-0.600	-1.68	+	-0.023
	June	-0.98	-	-0.532	0.89	-	0
	July	-1.90	+	-0.862	-1.69	+	-0.056
	August	-0.74	-	-0.243	-1.46	-	-0.053
	September	-0.19	-	-0.165	-0.40	-	0
	October	-1.16	-	-0.536	-0.78	-	0
	November	-1.41	-	0	-1.58	-	0

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

3.2 Seasonal rainfall and rainy days trend analysis: The seasonal rainfall trend was significant decreasing, for summer (Z= -3.82) at 99 per cent confidence level, south west monsoon (Z= -1.68) at 90 per cent confidence level and north east monsoon (Z= -2.43) at 95 per cent confidence level. The Q statistics showed nature of rainfall trends at Tasgaon tahsil during summer, south west monsoon and north east monsoon were significantly decreasing. The rainy days trend was significant decreasing, for the summer (Z= -4.19) at 99 per cent confidence level and for the north east monsoon (Z= -2.15) at 95 per cent confidence level. The Q statistics showed nature of rainy days trends at Tasgaon tahsil during summer and north east monsoon were significantly decreasing.

3.3 Monthly rainfall and rainy days trend analysis: The monthly rainfall trend was significant decreasing, for May (Z= -2.46) and July (Z= -1.90) at 95 per cent level of significance and 90 per cent level of significance, respectively. The Q statistics showed nature of rainfall trends at Tasgaon tahsil during May and July were significantly decreasing. The monthly rainy days trend was significant decreasing, for May (Z= -1.68) and July (Z= -1.69) at 90 per cent confidence level each. The Q statistics showed nature of rainy days trends at Tasgaon tahsil during May and July were significantly decreasing.

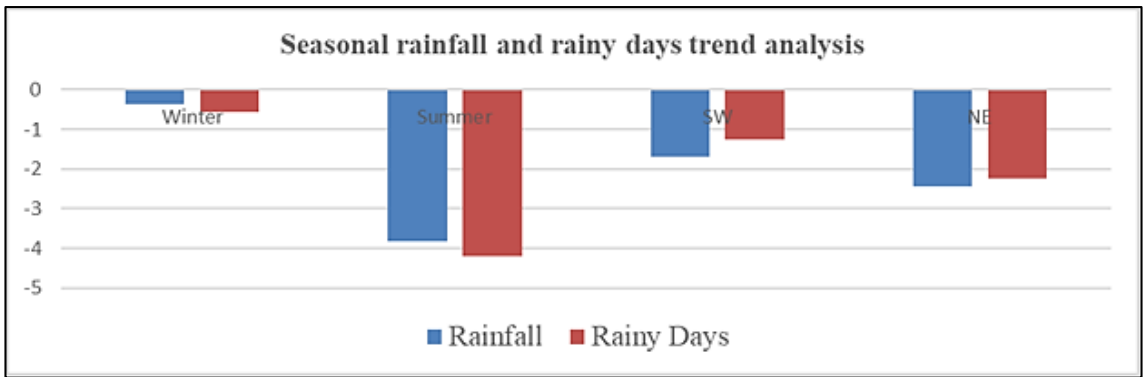

Fig 1: Seasonal trend in rainfall and rainy days

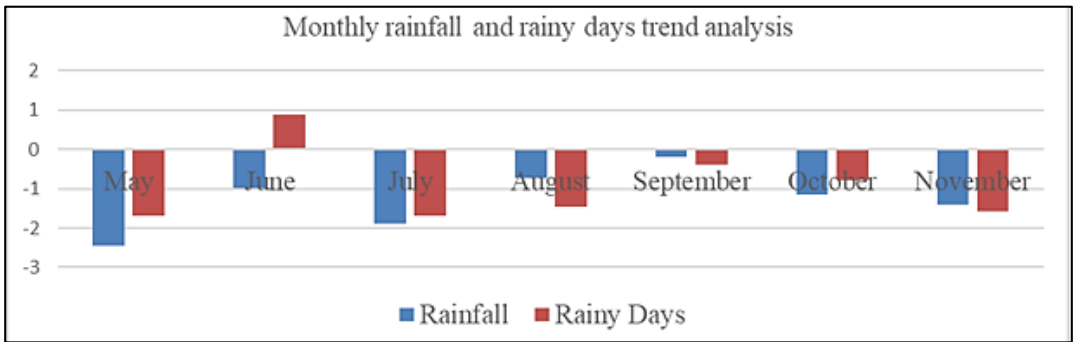

Fig 2: Monthly trend in rainfall and rainy days

4. Conclusions

The annual rainfall and rainy days data showed decreasing trend for Tasgaon tahsil. The seasonal rainfall and rainy days showed decreasing trend for all seasons *i.e.* summer, winter, northeast monsoon and southwest seasons. The monthly rainfall trend showed decreasing trend for all months *i.e.* May to November and the monthly rainy days trend showed decreasing trend in same month except the month of June which showed increasing trend.

Abbreviation: 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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