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Rainfall and Rainy Days Trend Analysis in Miraj Tahsil of Sangli District

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Abstract

The study has been carried out to investigate and asses the significance of the potential trend on annual, seasonal and monthly basis using the data period between 1982 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 increasing annual rainfall and rainy days trend over the tahsil. The seasonal rainfall and rainy days showed decreasing trend for summer season and decreasing trend for northeast monsoon and southwest monsoon seasons. The monthly rainfall and rainy days trend showed increasing trend for July to November months and decreasing days for May month. The weekly rainfall and rainy days trend showed decreasing trend for MW21-MW24, MW30, MW33 and MW43-MW45.

Key words : Rainfall trend, Rainy days trend, Mann Kendall method, Sen's slope method, Sangli, Miraj.

Climate is one of the key components in the earth system. There are many variables such as temperature, rainfall, atmospheric pressure, humidity that constitute weather and climate. The analysis of long-term changes in climatic variables is a fundamental task in studies on climate change detection. Global climate changes may influence long-term rainfall patterns impacting the availability of water, along with the danger of increasing occurrences of droughts and floods (Pal and Mishra, 2017). The rainfall and temperatures are the most important fundamental physical parameters among the climate as these parameters determine the environmental condition of the particular region which affects the agricultural productivity (Singh *et al*., 2013). 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, domestic water supply and for hydroelectric power generation. The pattern and amount of the rainfall are among the most vital factors that affect agricultural production and agriculture is dominant to India's economy and livelihood of its people (Gajbhiye *et al*., 2016; and Kumar and Gautam, 2014). The southwest monsoon brings about 80 per cent of the total precipitation over the country. Changes in the pattern, frequency and variability of monsoon would have a significant impact on agricultural production, water resources management and overall economy of the country (Sinha and Srivastava, 2000).

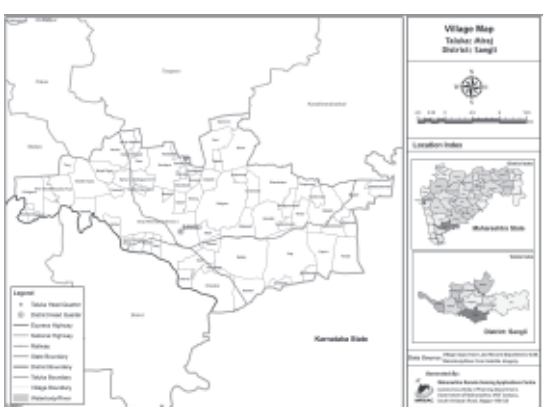
Sangli district is located in the western part of Maharashtra. It is situated between the 16°5'N to 17°33'N latitude and 73°41'E to 75°41'E longitudinal. The climate of Sangli district is generally hot and dry. The average annual rainfall of Sangli district is 603 mm with 41 rainy days (Wale, 2019). 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). One-third of the district receives assured rainfall, while the rest has to face the vagaries of the monsoon. (Anonymous, 2013).

Trend analysis of rainfall time series includes determination of increasing and decreasing trend and magnitude of trend and its statistical significance (Jain and Kumar, 2012) by using parametric and non-parametric statistical methods. Mann-Kendall test (Mann, 1945 and Kendall, 1975) is one of the best methods amongst them, which is preferred by various researchers (Jain and Kumar, 2012). Various studies were carried out to determine the trend of rainfall (Kumar *et al*., 2010, Athar, 2015, Duhan and Pandey, 2013; Duan *et al*., 2017, Sahu *et al*., 2012, 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). The major objective of this study is to determine and analyse the trends of the precipitation, runoff and temperature on weekly, monthly, seasonal and annual basis.

Materials and Methods

Study area : Miraj is a tahsil of Sangli district situated between the 16.850° latitude and 74.610°E longitudinal. The total geographical area of the tahsil is 800.10 km^2 (District Socio-economic Statistical Abstract, 2011). The average annual rainfall of Miraj tahsil is 681.10 mm and 45 average rainy days. The major source of income for people is from agriculture.



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 1982 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).

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);

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

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

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

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

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

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).

To derive an estimate of the slope Qt, 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 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 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 1982 to 2018 year rainfall and rainy days data is shown in Table 1.

Table 1. Rainfall and rainy days trend analysis at Miraj tahsil

Time series	Rainfall (mm)			Rainy days		
	Test Z	Sign-ific.	Q	Test Z Z	Sign-ific.	Q
Annual	0.72	-	2.235	1.43	-	0.234
Seasonal						
Winter	0	-	0	0	-	0
Summer	-1.94	+	-0.325	-1.31	-	0
SW	1.06	-	2.604	2.07	*	0.292
NE	0.85	-	1.267	0.68	-	0
Monthly						
May	-1.94	+	-0.325	-1.31	-	0
June	-1.11	-	-1.038	0.22	-	0
July	1.10	-	0.852	1.06	-	0.053
August	0.81	-	0.673	1.22	-	0.082
September	0.88	-	0.602	2.05	*	0.100
October	0.88	-	1.242	0.75	-	0
November	0.08	-	0	0.04	-	0

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

Annual rainfall and rainy days trend analysis : The test results showed that annual rainfall and annual rainy data of Miraj tahsil over the 37 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 increasing trend of annual rainfall and annual rainy days.

Seasonal rainfall and rainy days trend analysis : The seasonal rainfall at Miraj tahsil during the summer season exhibited significant trend at 90 per cent level of significance. The rainfall trend was significant decreasing (Z= -1.94) at 90 per cent confidence level. The seasonal rainy days at Miraj tahsil during the south west monsoon exhibited significant trend at considered level of significance. The trend was significant increasing, for the south west monsoon (Z= 2.07) at 95 per cent confidence level. The Z statistics and Q statistics showed nature of rainy days trends at Miraj tahsil during south west monsoon was significantly increasing and rainfall during summer season was significantly decreasing.

Monthly rainfall and rainy days trend analysis : The monthly rainfall at Miraj tahsil during the month of May exhibited significant trend at 90 per cent level of significance. The trend was significant decreasing (Z= -1.94) at 90 per cent confidence level. The Z statistics and Q statistics showed nature of rainfall trends at Miraj tahsil during May was significantly decreasing. The monthly rainy days at Miraj tahsil during the month of September exhibited significant trend at considered level of significance. The trend was significant increasing, for the month of September (Z= 2.05) at 95 per cent confidence level. The Z statistics and Q statistics showed nature of rainy days trends at Miraj tahsil during September was significantly increasing.

Weekly rainfall and rainy days trend analysis : Rainfall trend at Miraj tahsil during 21-24, 26, 28-34, and 37-46 MWs didn't

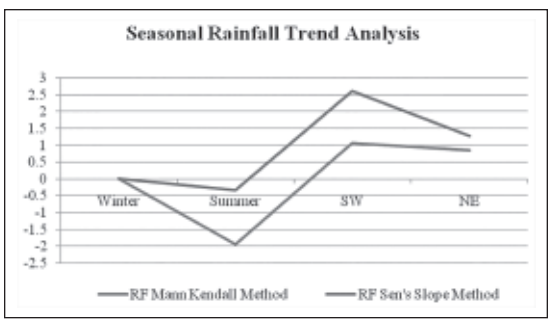


Fig. 2. Seasonal Rainfall trend analysis

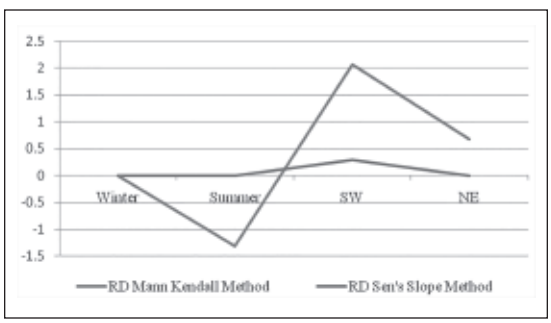


Fig. 3. Seasonal rainy days trend analysis

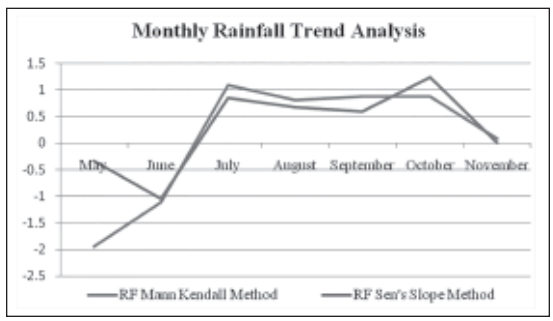


Fig. 4. Monthly Rainfall trend analysis

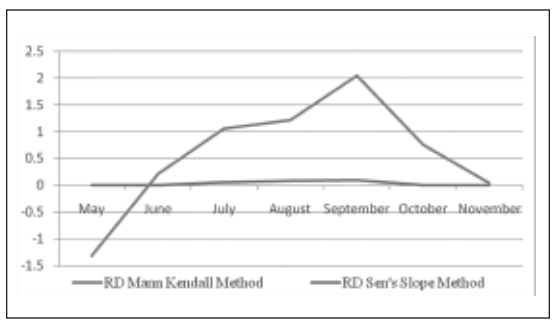


Fig. 5. Monthly rainy days trend analysis

Table 2. Rainfall and rainy days trend analysis at Miraj tahsil

Time series	Rainfall			Rainy days		
	Test Z	Signific.	Q	Test Z Z	Signific.	Q
MW 21	-0.75	-	0	-1.03	-	0
MW 22	-0.78	-	0	-0.63	-	0
MW 23	-0.94	-	-0.105	-0.94	-	0
MW 24	-1.24	-	-0.257	-1.07	-	0
MW 25	1.77	+	0.361	2.21	*	0.03
MW 26	-0.61	-	-0.155	0.18	-	0
MW 27	1.94	+	0.196	1.62	-	0
MW 28	1.12	-	0.203	0.93	-	0
MW 29	0.63	-	0.158	0.69	-	0
MW 30	-0.41	-	-0.113	-0.08	-	0
MW 31	-0.05	-	0	0.60	-	0
MW 32	-0.18	-	-0.038	0.05	-	0
MW 33	-0.51	-	-0.058	-0.03	-	0
MW 34	0.55	-	0.043	0.60	-	0
MW 35	2.34	*	0.331	1.46	-	0
MW 36	2.31	*	0.333	1.79	+	0
MW 37	1.06	-	0	0.73	-	0
MW 38	-0.56	-	0	0.24	-	0
MW 39	1.28	-	0.604	2.16	*	0.048
MW 40	0.97	-	0.500	0.52	-	0
MW 41	1.01	-	0.132	1.24	-	0
MW 42	0.44	-	0	0	-	0
MW 43	-0.17	-	0	-0.12	-	0
MW 44	-0.72	-	0	-0.82	-	0
MW 45	-0.30	-	0	-0.34	-	0
MW 46	0.22	-	0	0.20	-	0

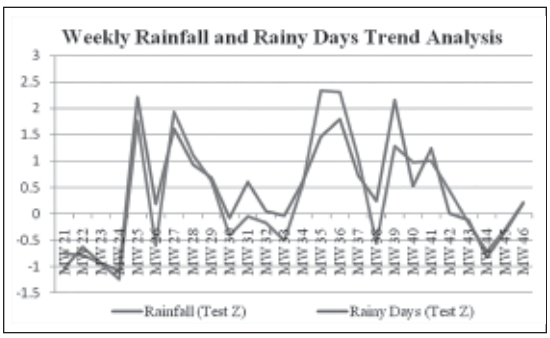


Fig. 6. Weekly Rainfall and Rainy Days trend Analysis for Mann Kendall Method

exhibit any statistical significant trend at confidence levels. MW 25 (18 June to 24 June) and MW 27 (2 July to 8 July) exhibited statistical significance increasing rainfall trend (Z= 1.77) and (Z= 1.94) at 90 per cent confidence level. MW 35 (27 Aug. to 2 Sep.) and MW 36 (3 Sep. to 9 Sep.) exhibited statistical significance increasing rainfall trend (Z= 2.34) and (Z= 2.31) respectively, at 95 per cent confidence level. Rainy days trend at Miraj tahsil during 21-24, 26-35, 37-38 and 40-46 MWs didn't exhibit any statistical significant trend at confidence levels. MW 25 (18 June to 24 June) and MW 39 (24 Sep. to 30 Sep.) exhibited statistical significance increasing rainy days trend (Z= 2.21) and (Z= 2.16) at 95 per cent confidence level. MW 36 (3 Sep. to 9 Sep.) exhibited statistical significance increasing rainy days trend (Z= 1.79) at 90 per cent confidence level.

Conclusions

The annual rainfall and rainy days data showed increasing trend for Miraj tahsil. The seasonal rainfall and rainy days showed decreasing trend for summer season and decreasing trend for northeast monsoon and southwest monsoon seasons. The monthly rainfall and rainy days trend showed increasing trend for July to November months and decreasing days for May month. While June month shows decreasing trend for rainfall and increasing trend for rainy day. The weekly rainfall and rainy days trend showed decreasing trend for MW21-MW24, MW30, MW33 and MW43-MW45. The weekly rainfall trend showed increasing trend for MW25, MW27-MW29, MW34-MW37, MW39-MW42 and MW46. The weekly rainy days trend showed increasing trend for MW25-MW29, MW31, MW32, MW34-MW41 and MW46.

Abbreviation

Km : Kilometre; Km^2 : Kilometre square; °N : Degree North, °E : Degree East; IMD : India Meteorological Department; No. : Number; mm : Millimetre; Signific. : Significant; *et al*. : and

others ; SW : southwest; NE : Northeast and ha : Hector; MW : Meteorological Week.

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