J. Agric. Res. Technol., 47 (1) : 055-060 (2022) https://doi.org/10.56228/JART.2022.47111

Trend Analysis of Rainfall and Rainy Days using Mann Kendall Method and Sen's Slope Estimator Atpadi Tahsil of Sangli District of Maharashtra

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(Received : 08.06.2021 Accepted : 28.06.2021)

Abstract

The study has been carried out to investigate and assess the significance of the potential trend of rainfall and rainy days over the Atpadi tahsil of Sangli district of Maharashtra. In this study, trend analysis has been carried out on annual, seasonal, monthly and weekly 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 rainfall and rainy days trend over the Atpadi tahsil for annual, seasonal (winter and southwest monsoon), monthly (June, August and September) and weekly (MW23, MW25, MW27, MW31, MW34-MW37, MW42 and MW46) time series.

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

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.

Sangli district is located in the western part of Maharashtra. It is situated between the 16°5N to 17°33N latitude and 73°41E to 75°41E 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). In the district, 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 (Gedefaw, M. *et al.*, 2018; John and Brema 2018; Pal *et al.*, 2017; Easterling *et al.*, 2000; Francis and Gadgil, 2006; Griffiths *et al.*,

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2003; Guhathakurta and Rajeevan, 2006; Haylock, 2006 and Kunkel, 2003).

Materials and Methods

Study area : Atpadi is a taluka located in Sangli district of Maharashtra. It is situated between the 17.420°N latitude and 74.937°E longitudinal. The total geographical area of the tahsil is 863.56 km^2. (District Socio-economic Statistical Abstract, 2011). The normal annual rainfall of Atpadi tahsil is 414.40 mm and 28 normal rainy days. The region falls under the rain-shadow area resulting in less rain. Jowar, maize, wheat, cotton, sugarcane, bajari and pomegranate are the main agricultural produce in Atpadi. The low monsoon rainfall is advantageous to farmers as the pomegranate is a desert tree.

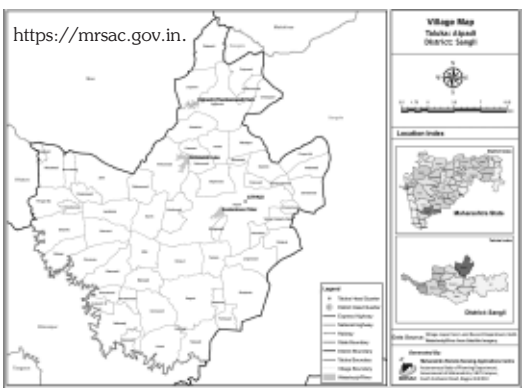

Fig. 1. Map of Atpadi Tasils of Sangli districts

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 thirty seven 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);

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

Where, X_j and X_k are the annual values in year's j and k, j > k respectively and Xk represent the data point at time k.

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

The value of sign (x_j - x_k) is computed as number follows

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 tp = number of items in the tied group

Calculate a normalized test statistic Z by the following equation

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

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

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

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.

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).

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

To derive an estimate of the slope Qt, the slope of all data pairs was calculated;

If there are n values of X_j 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

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

N values of Qt were ranked from the smallest to the largest and the sen's estimate was calculated as;

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.

Results 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.

Annual rainfall and rainy days trend analysis : The test results showed that annual rainfall and annual rainy days of Atpadi 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 and rainy days trend at Atpadi tahsil during the summer, winter, south west monsoon and north east monsoon season didn't exhibit any significant trend at considered level of significance.

Monthly rainfall and rainy days trend analysis : The monthly rainfall at Atpadi tahsil during the month of June exhibited significant trend at 90 per cent level of significance. The trend was significant increasing (Z= 1.78) at 90 per cent confidence level. The Z statistics and Q statistics showed nature of rainfall trends at

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

Time series	Rainfall (mm)			Rainy days		
	Test Z	Sign-ific.	Q	Test Z Z	Sign-ific.	Q
Annual	0.48	-	1.632	1.02	-	0.132
Seasonal						
Winter	0.42	-	0	0.07	-	0
Summer	0.20	-	0	-0.26	-	0
SW	0.71	-	1.550	1.15	-	0.167
NE	-0.92	-	-1.000	-0.16	-	0
Monthly						
May	-0.44	-	0	-0.54	-	0
June	1.78	+	1.157	0.47	-	0
July	-0.95	-	-0.451	-0.05	-	0
August	0.24	-	0.127	0.59	-	0
September	0.44	-	0.406	0.60	-	0
October	-0.76	-	-0.894	-0.21	-	0
November	-0.12	-	0	0.46	-	0

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

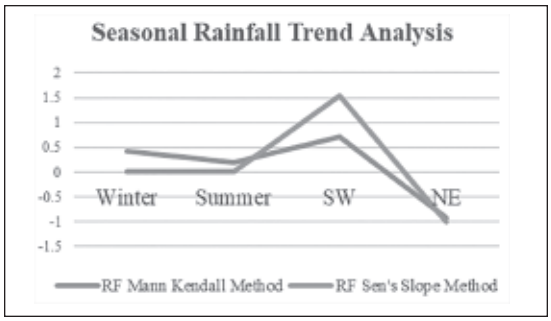

Fig. 2. Seasonal Rainfall trend analysis

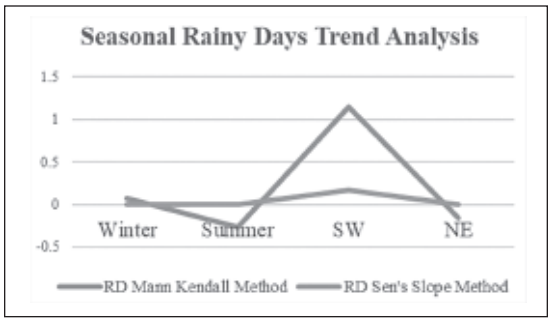

Fig. 3. Seasonal Rainfall trend analysis

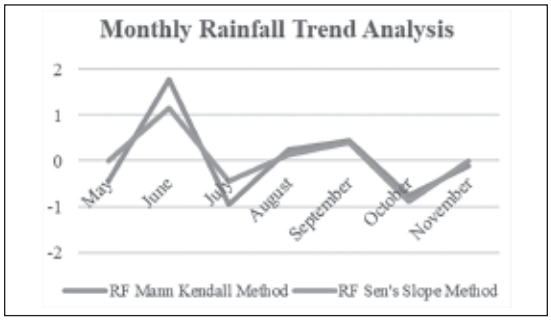

Fig. 4. Monthly Rainfall trend analysis

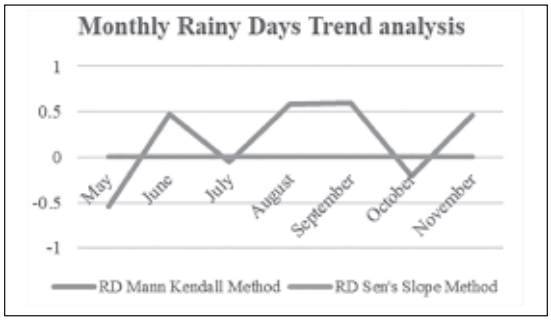

Fig. 5. Monthly rainy days trend analysis

Table 2. Weekly rainfall and rainy days trend analysis at Atpadi tahsil

Time series	Rainfall			Rainy days		
	Test Z	Sign-ific.	Q	Test Z Z	Sign-ific.	Q
MW 21	-1.01	-	0	0.03	-	0
MW 22	-0.03	-	0	0.12	-	0
MW 23	2.64	**	0.498	1.73	+	0
MW 24	-0.73	-	-0.058	-0.89	-	0
MW 25	1.20	-	0.054	0.78	-	0
MW 26	-1.28	-	0	-1.03	-	0
MW 27	1.49	-	0	1.52	-	0
MW 28	-0.58	-	0	-0.03	-	0
MW 29	-0.93	-	0	-0.95	-	0
MW 30	-0.84	-	-0.025	-0.35	-	0
MW 31	0.12	-	0	0.27	-	0
MW 32	-1.11	-	0	-1.06	-	0
MW 33	-1.57	-	-0.080	-1.26	-	0
MW 34	1.65	+	0.030	2.11	*	0
MW 35	1.99	*	0.139	1.37	-	0
MW 36	2.00	*	0.250	1.46	-	0
MW 37	0.59	-	0.049	0.34	-	0
MW 38	-0.16	-	0	0.17	-	0
MW 39	-0.76	-	-0.174	-1.02	-	0
MW 40	-0.10	-	0	-0.26	-	0
MW 41	-0.41	-	0	-0.30	-	0
MW 42	0.73	-	0	0.68	-	0
MW 43	-0.43	-	0	-0.52	-	0
MW 44	-0.89	-	0	-0.77	-	0
MW 45	-0.27	-	0	-0.24	-	0
MW 46	0.98	-	0	1.01	-	0

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

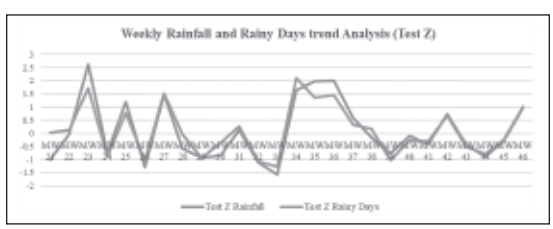

Fig. 5. Monthly rainy days trend analysis

Atpadi tahsil during June was significantly increasing. The monthly rainy days at Atpadi tahsil during the month of May, June, July,

August, September, October and November didn't exhibit any significant trend at considered level of significance.

Weekly rainfall and rainy days trend analysis : Rainfall trend at Atpadi tahsil during 21-22, 24-33 and 37-46 MWs and rainy days trend at Atpadi tahsil during 21-22, 24-33 and 35-46 MWs didn't exhibit any statistical significant trend at confidence levels. MW 23 (4 June to 10 June) exhibited statistical significance increasing rainfall trend (Z= 2.64) at 99 per cent confidence level and increasing rainy days trend (Z= 1.73) at 90 per cent confidence level. MW 34 (20 Aug. to 26 Aug.) exhibited statistical significance increasing rainfall trend (Z= 1.65) at 90 per cent confidence level and increasing rainy days trend (Z= 2.11) at 95 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= 1.99) and (Z= 2.00) respectively, at 95 per cent confidence level.

Conclusions

The annual rainfall and rainy days data showed increasing trend for Atpadi tahsil. The seasonal rainfall and rainy days data showed increasing trend for winter and southwest monsoon seasons, and decreasing trend for northeast monsoon season and also decreasing trend for summer rainy days. The monthly rainfall and rainy data showed decreasing trend for May, July and October months, and increasing trend for June, August and September months, while increasing trend in the month of November rainy days. The weekly rainfall data showed increasing trend for MW23, MW25, MW27, MW31, MW34-MW37, MW42 and MW46. The weekly rainy days data showed increasing trend for MW21-MW23, MW25, MW27, MW31, MW34-MW38, MW42 and MW46.

References

Anonymous. 2013. A report of Maharashtra water resource regulatory authority. Water Resource Department, Government of Maharashtra.

Anonymous. 2015. Economic survey of Maharashtra, Directorate of Economic and Statistics, Planning Department, Govt. of Maharashtra, Mumbai.

Easterling, D. R., Evans, J. L., Groisman, P. Y., Karl, T. R. and Ambenje, P. 2010. Observed variability and trend in extreme climate events: a brief review. Bulletin of the American Meteorological Society. 81: 417-425.

Francis, P. A. and Gadgil, S. 2006. Intense rainfall events over the west coast of India. Meteorological Atmospheric Physics. Doi 10.1007/s00703-005-0167-2.

Gedefaw, M., Yan, D., Wang, H., Qin, T., Girma, A., Abiyu, A. and Batsuren, D. 2018. Innovative trend analysis of annual and seasonal rainfall variability in Amhara regional state, Ethiopia. Atmosphere, 9,326: 1-10.

Government of Maharashtra, 2011. District Socio-Economic Review and Statistical Abstract of Sangli District.

Griffiths, G. M., Salinger, M. J.and Leleu, I. 2003. Trends in extreme daily rainfall across the south Pacific and relationship to the South Pacific convergence zone. International Journal of Climatology. 23: 847-867.

Guhathakurta, P. and Rajeevan, M. 2006. Trends in the rainfall pattern over India. NCC Research Report No 2/2006, Indian Meteorological Department, pp. 23.

Heylock, M. R. 2006. Trends in total and extreme South American rainfall in 1969-2000 and links with sea surface temperature. J. of Climate. 19: 1490-1512.

Jain, S. K. and Kumar, V. 2012. Trend analysis of rainfall and temperature data for India. Current Science, 102(1): 37-49.

John, A. S. and Brema, J. 2018. Rainfall trend analysis by Mann kendall test for Vamanapuram river basin, Kerala. International Journal of Civil Engineering and Technology. 9(13): 1549-1556.

Kendall, M. G. 1975. Rank correlation methods, Charles Griffin, London.

https://mrsac.gov.in.

Mann, H. B.1945. Nonparametric tests against trend. Econometrica.13: 245-259.

Pal, A. B., Khare, D., Mishra, P. K. and Singh, L. 2017. Trend analysis of rainfall, temperature and runoff data : A case study of Rangoon watershed in Nepal. International Journal of Students Research In Technology and Management. 5(3): 21-38.