The Pharma Innovation Journal 2023; 12(6): 3531-3532

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2023; 12(6): 3531-3532

www.thepharmajournal.com
Received: 19-03-2023
Accepted: 22-04-2023

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Trend analysis of rainfall and temperature in Akola using Mann-Kendall trend test and Sen's slope estimator

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Abstract
Climatic variability of Akola was studied using 24 year meteorological data *i.e.* from 1998 to 2021. The monthly and yearly rainfall, minimum and maximum temperature data were used to study the trend analysis using Mann-Kendall and Sen's slope method. The results obtained from M-K test showed that trend of annual Rainfall is decreasing over the region by about 5.84 mm/year. Minimum temperature is increasing over the region by about 0.03 °C per annum, while maximum temperature is decreasing by about 0.03 °C per annum for Akola station.

Keywords: Trend analysis, rainfall, Mann-Kendall, Sen's slope

Introduction
Climate change and its impact are now real but different effect can be seen in different places. The negative impact of climate change along with the increasing population is making agriculture more challenging. Accurate information about climatic parameter and their trend is important for crop and irrigation planning. Climate change and agriculture are interrelated process, both of which takes place on global scale. Agriculture is the foundation for basic humanity needs and since ages, it has been satisfying the food, nutrition and livelihood requirements of the ever-growing population. The global food security threatened by climate change is one of the most important challenges in the 21st century to supply sufficient food for increasing population while sustaining the already stressed natural resources and environment.

Material and Method
Akola is situated in Western Vidarbha region of Maharashtra State and comes under subtropical zone. It is situated at an altitude of 307.415 m above mean sea level at the intersection of 20º 42' North latitude and 77º 02' East longitude. Yearly rainfall, minimum and maximum temperature data for the period of 24 years i.e. from 1998 to 2021 was used to study the climatic variability of Akola.

Mann-Kendall Test (M-K)
The Mann-Kendall test is a non-parametric test for identifying trends in time series data. The data values are evaluated as an ordered time series. Each data value is compared to all subsequent data values. Let x_1,x_2, x_3…., x_n represent n data points where x_j represents the data point at time j. Then the Mann-Kendall statistic (S) is given by

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sign\left(x_j - x_k\right) \quad (1)$$

$$sign(x_j - x_k) = \begin{cases} 1\ if\ (xj - x_k) > 0 \\ 0\ if\ (x_j - x_k) = 0 \\ -1\ if\ (x_j - X_k) < 0 \end{cases}$$

A very high positive value of S is an indicator of an increasing trend, and a very low negative value indicates a decreasing trend. However, it is necessary to compute the probability associated with S and the sample size, n, to statistically quantify the significance of the trend.

$$VAR(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p+1}^{q} t_p(t_p-1)(2t_p+5)\right] \quad (2)$$

$$Z = \begin{cases} \dfrac{s-1}{\sqrt{VAR(S)}} \; if \; S > 0 \\ 0 \; if \; S > 0 \\ \dfrac{s+1}{\sqrt{VAR(S)}} \; ifs > 0 \end{cases}$$

The presence of a statistically significant trend was evaluated using Z value. The statistic Z has a normal distribution. To test for either an upward or downward monotone trend (a two-tailed test) at α level of significance, H_0 was rejected if the absolute value of Z was greater than Z_1-α/2, where Z_1-α/2 is obtained from the standard normal cumulative distribution tables.

Sen's Slope Estimator Test

If a linear trend is present in a time series, then the true slope (change per unit time) was estimated by using a simple nonparametric procedure developed by Sen (1968) [3]. Linear model f(t) can be described as

$$f(t) = Q_t + B \quad (3)$$

To derive an estimate of the slope Q_t the slopes of all data pairs were calculated

$$Q_t = \frac{x_j - x_k}{j-k}, i = 1,2,3 \ldots N, j > k \quad (4)$$

If there was n values, x_j in the time series can as many as N = n(n-1)/2, for slope estimates Q_t. The Sen's estimator of slope is the median of these N values of Q_t. The N values of Q_t was ranked from the smallest to the largest and the Sen's estimate as

$$Qt = \begin{cases} Q_{\frac{N+1}{2}} & if \; N \; is \; odd \\ \frac{1}{2}\left(Q_{\frac{N}{2}} + Q_{\frac{N+2}{2}}\right) & if \; N \; is \; even \end{cases} \quad (5)$$

To obtain an estimate of B in equation (3), the values of differences $x_i - Q_t$ was calculated. The median of these values gives an estimate of B (Sirois, 1998). The estimate for the constant B of lines of 99% and 95% confidence intervals was calculated by a similar procedure.

Result and Discussion

Yearly trend analysis

The results of Mann-Kendall test and Sen's slope estimator i.e. trend of yearly rainfall, minimum and maximum temperature presented in Table 1 and 2 For analysis, data from 1998-2021 i.e. 24 years was used.

Table 1: Yearly trends of rainfall, minimum and maximum temperature using M-K test

Annual time series	Rainfall			Minimum Temperature			Maximum Temperature		
	Test Z	Sig.	Trend	Test Z	Sig.	Trend	Test Z	Sig.	Trend
Akola	-0.87		No	2.41	*	Inc.	-1.22		No

From Table 1, the Mann-Kendall test results shows that annual rainfall of Akola station over 24 years didn't exhibit any statistically significant trend at the significance levels. But the test shows that trend of annual rainfall was non-significant decreasing (Z=-0.87) at non-significant confidence levels. The nature of rainfall trend of Akola station over 24 years was decreasing at non-significant confidence level. The test exhibited increasing trend (Z=2.41) for minimum temperature at significant confidence level of 90%, while maximum temperature didn't exhibit any statistically significant trend but the test shows that trend of maximum temperature was non-significant decreasing (Z=-1.22) for Akola station.

Table 2: Monthly trends of rainfall, minimum and maximum temperature using Sen's slope estimator

Annual time series	Rainfall			Minimum Temperature			Maximum Temperature		
	Q_t	Sig.	Trend	Q_t	Sig.	Trend	Q_t	Sig.	Trend
Akola	-5.84		No	0.03	*	Inc.	-0.03		No

From Table 2, Sen's slope test shows that annual rainfall of Akola station over 24 years did not exhibit any statistically significant trends at the considered confidence level. But the Sen's slope test shows that the trend of annual rainfall was non-significant decreasing (Qt=-5.84) at non-significant confidence level. It indicates that trend of annual rainfall at Akola station was decreasing about -5.84 mm/year. Whereas Sen's slope test shows that the trend of minimum temperature was significant increasing (Qt=0.03) at significant confidence level of 90%, while trend of maximum temperature was non-significant decreasing (Qt=-0.03) at non-significant confidence level. It indicates that trend of minimum temperature in Akola station was increasing about 0.03 °C/year, while that of maximum temperature in Akola station was decreasing by about 0.03 °C/year.

Conclusion

Rainfall is decreasing over the region by about 5.84 mm/year. Minimum temperature is increasing over the region by about 0.03 °C per annum, while maximum temperature is decreasing by about 0.03 °C per annum for Akola station.

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