International Journal of Agricultural Sciences
Volume 17 | Issue 1 | January, 2021 | 19-25 ■ ISSN : 0973-130X
DOI:10.15740/HAS/IJAS/17.1/19-25
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RESEARCH PAPER

Trend analysis of rainfall using Mann-Kendall, Sen's slope, moving average and least square techniques for Ahmednagar district of Maharashtra

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Abstract : The long-term behaviour of rainfall is necessary to study over space with different time series *viz.,* annual, monthly and weekly as it is one of the most significant climatic variables. Rainfall trend is an important tool which assesses the impact of climate change and provides direction to cope up with its adverse effects on the agriculture. Several studies have been performed to establish the pattern of rainfall over various time periods for different areas that can be used for better agricultural planning, water supply management, etc. Consequently, the present report, entitled "Trend analysis of rainfall in Ahmednagar district of Maharashtra," was carried out. 13 tahsils of the district of Ahmednagar were selected to carry out trend analysis. The daily rainfall data of 33 years (1980- 2012) of all stations has been processed out study the rainfall variability. The Mann Kendall (MK) Test, Sen's slope method, moving average method and least square method were used for analysis. The statistical analysis of whole reference time series data highlighted that July and August month contributes highest amount of rainfall at all tahsils. Regarding trend in annual rainfall, these four methods showed increasing trend at most of the tahsils whereas a decreasing trend only at Shrigonda tahsil. For monthly trend analysis, Kopargaon, Newasa, Shevgaon and Shrirampur tahsils showed an increasing trend during July. During August and September month, most of the tahsils *i.e.* Kopargaon, Nagar, Parner and Sangamner showed increasing trends, whereas in June, only Shrigonda tahsil showed decreasing trend.

Key Words : Rainfall, Mann-Kendall, Sen's Slope, Moving average, Least square, trend

View Point Article : Barai, Virendra N. and Kalunge, Rohini M. (2021). Trend analysis of rainfall using Mann-Kendall, Sen's slope, moving average and least square techniques for Ahmednagar district of Maharashtra. *Internat. J. agric. Sci.*, **17** (1) : 19-25, **DOI:10.15740/HAS/IJAS/17.1/19-25.**

Article History : Received : 12.10.2020**; Revised :** 06.11.2020**; Accepted :** 08.12.2020

INTRODUCTION

Agriculture and related sectors, food security and energy security of India are crucially dependent on the timely availability of adequate amount of water and a conducive climate. The rainfall received in an area is an important factor in determining the amount of water available to meet various demands. Global climate changes may influence long-term rainfall patterns impacting the availability of water, along with the danger

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of increasing occurrences of droughts and floods. Due to the uneven distribution of rainfall and the mismatch between water availability and demand, large storage reservoirs are required to redistribute the natural flow in accordance with the requirements of specific regions. Changes in rainfall due to global warming will influence the hydrological cycle and the pattern of stream-flows and demands (particularly agricultural), requiring a review of hydrologic design and management practices. Changes in run-off and its distribution will depend on likely future climate scenarios. The trend analysis of rainfall, temperature and other climatic variables on different spatial scales will help in the construction of future climate scenarios (Jain *et al*., 2012).

Variation in the monsoon rainfall has both social and economic impact, as in India, agriculture largely depends on rainfall. Therefore, study of trend in rainfall pattern is essential for better planning and adaptation for extreme events. Trend may be loosely defined as "long-term change in the mean level", but there is no fully satisfactory mathematical definition. However, trend analysis helps in 'forecasting'. The base of scientific forecasting is statistics. Trend analysis was carried out to examine the long-term trends in rainfall over different subdivisions. The rainfall 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 more accurate information about meteorological parameters and their trends are also needed for the formulation of weather model, which will help to improve sustainability of water resource management planning.

Therefore, the trend analysis of rainfall will be useful to construct the future scenario of water availability. The trend analysis of the weekly, monthly and annual rainfall data of the Ahmednagar district has been an attempt to study the variations and trend of rainfall of the selected tahsils which will be useful for forecasting the future temporal and spatial availability of water. The future of a country largely depends on the effective development, utilization and management of these resources in an integrated and comprehensive manner.

MATERIAL AND METHODS

Description of study area:

The study area of this research is the Ahmednagar district in state of Maharashtra in India. There are 14 tahsils in Ahmednagar district. It is situated partly in upper Godavari basin and partly in the Krishna basin. It lies between 18.2º to 19.9º North latitude and 73.9º to 57.5º East longitude.

The climate of the district is hot and dry. Major part of the district experiences hot summer and dryness all throughout the year except during south-west monsoon season. The period from March to the first week of June is the hot season. It is followed by the south-

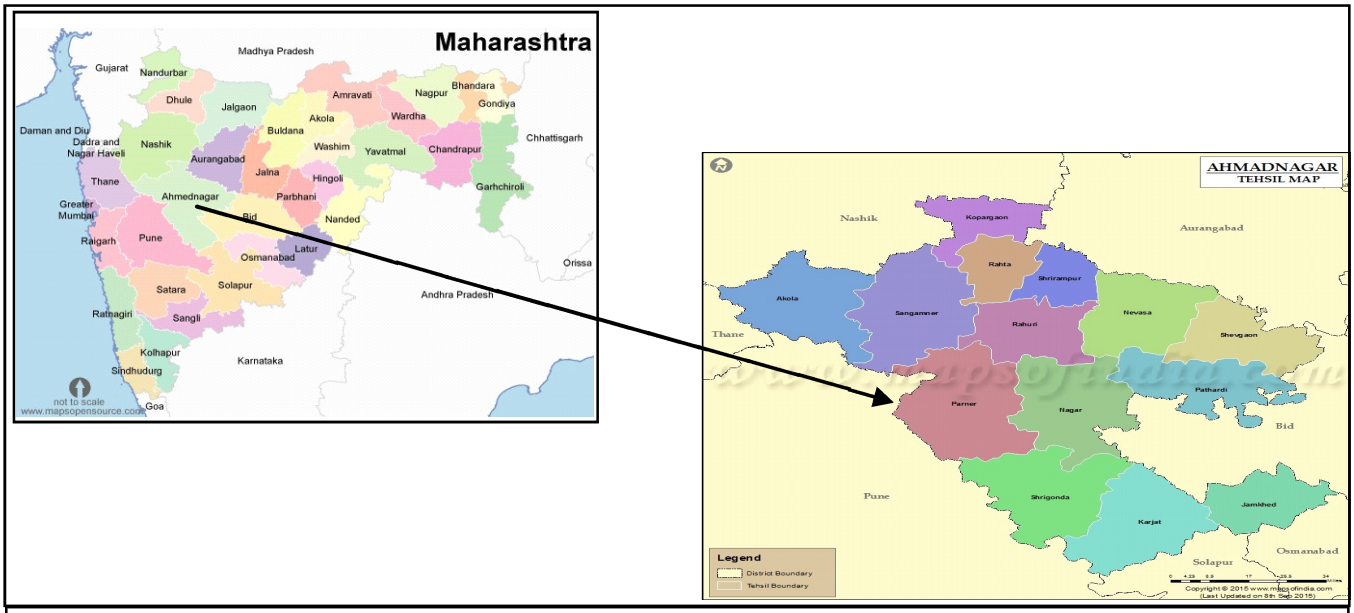

Fig. A : Study area showing location of 13 tahsil

west monsoon season which lasts till the end of September, October and November constitute the post-monsoon or the retreating south-west monsoon. Ahmednagar district gets rainfall mainly from south-west monsoon but the distribution of rain is mostly uneven. Agro-climatically, the district falls in drought prone area. The average rainfall of the district is between 566 mm. Location Map of Ahmednagar district showing the taluka boundaries as presented in Fig. A.

Data collection:

The required daily rainfall data of Akole, Jamkhed, Karjat, Kopargaon, Nagar, Newasa, Parner, Pathardi, Rahata, Sangamner, Shevgaon, Shrigonda and Shrirampur tahsils were obtained from the State Data Storage Centre, Hydrology Project (Surface Water) Jal Vidnyan Bhavan, Nashik and downloaded from *www.mahara in.gov.in* for the period of 1980-2012 (33 years) from the month of June to December. These data were used for trend analysis.

Software/ Programme:

Microsoft office sub-module MS-Excel was used for data analysis. The formulation and conditional statements were also executed in MS-excel. MAKESENS excel template was used for trend detection and estimation of magnitude of trend (Salmi *et al.,* 2002).

Rainfall variation:

The variation in rainfall has greater impact on agriculture, subsequently on economic and social life of human beings. Hence, it is important to study rainfall. The necessity of irrigation is determined by the amount of rainfall received during the period when the crops need it to survive. The success of the crops depends on the rainfall during monsoon (Tadvi, 2016). Hence, rainfall variation was estimated by calculating Mean, Standard deviation and co-efficient of variation.

Rainfall trend analysis:

Trend analysis was statistically examined in two phases *i.e.*, initially the presence of a monotonic increasing or decreasing trend was tested using the non-parametric Mann Kendall test (Mann, 1945 and Kendall, 1975) and the rate of change was estimated with the help of Sen's slope method (Sen, 1968). The slope of the trend indicates the rate and direction of change (Helsel and Hirsch, 2002; Drapela and Drapelova, 2011 and Choudhury *et al*., 2012). Then trend is also calculated and computed by the moving average and least square method.

In the present study, an excel template MAKESENS was used. The procedure of MAKESENS is based on the non-parametric Mann Kendall test for the trend and the non-parametric Sen's slope method for the magnitude of the trend. The Mann Kendall test was applicable to the detection of a monotonic trend of a rainfall time series and Sen's slope method was used to determine the magnitude of rainfall trends and linear model for the trend. The trend of rainfall data was analyzed in annual, monthly and weekly time series.

Mann Kendall test (M-K):

This is a statistical method which is mostly used to check the Null hypothesis of no trend versus the alternative hypothesis of the existence of monotonic increasing or decreasing trend of hydro-climatic time series data. The non-parametric Mann Kendall test is fit for those data series where the trend may be assumed to be monotonic (*i.e.* mathematically the trend consistently increasing and never decreasing or consistently decreasing and never increasing) and no seasonal or other cycle is present.

For time series with less than 10 data points the S test was used and for time series with 10 or more data points the normal approximation (Z) was used (Gilbert, 1987). Based on normalized test statistics (Z) value, the trend is said to be decreasing if Z is negative and increasing if the Z is positive. The number of annual values in the data series is denoted by *n*.

The presence of a statistically significant trend was evaluated using Z value. A positive/negative value of Z indicates an upward /downward trend. In the present study, the value of test statistics is computed at confidence level of 99, 95 and 90 per cent. At the 99 per cent significance level, the Null hypothesis of no trend is rejected if $|Z| > 2.575$; at the 95 per cent significance level, the Null hypothesis of no trend is rejected if $|Z| > 1.96$ and at the 90 per cent significance level, the Null hypothesis of no trend is rejected if $|Z| > 1.645$.

Sen´s slope method:

Sen's slope method has been used for predicting the magnitude (true slope) 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 Q_t, the slopes of all data pairs were calculated

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

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:

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

Median of all slope value gives Q_t, which is magnitude of trend. Positive value indicates increasing and negative value indicates decreasing trend of rainfall.

Moving average method:

Moving average method is a simple means for reducing fluctuations and obtaining trend values with a fair degree of accuracy. The moving averages a series of successive averages secured from a series of values by averaging groups of successive values of the series. When a trend is to be determined by the method of moving average, the average value for a number of years is (months or weeks) is secured and this average is taken as the normal or trend value for the unit of time falling at the middle of the period covered in the calculation of the period. To compute three yearly moving average, for instance, the values of Ist, 2nd and 3rd years are added up and the quotient is placed against 2nd year; then values of the 2nd, 3rd and 4th years are added up, averaged and the average is placed against the year and so on (Yogish, 2007).

Least square method:

It is one of the most popular methods of overcoming fluctuations in a time series is to fit an appropriate curve to a given data. The method of least squares is to fit a mathematical device which places a line through a series of plotted points in such a way that the sum of the squares of the deviations of the actual points above and below the trend line is at the minimum. The method of least squares gives us what is known as the line of best fit. It is a line from which the sum of the deviations of various points on either side is equal to zero is known as to method of least squares (Yogish, 2007).

RESULTS AND DISCUSSION

The daily rainfall data were used to compute weekly, monthly and annual rainfall at all the 13 tahsils. The statistical parameters *viz.,* mean, standard deviation and co-efficient of variation were determined are presented in Table 2. The annual rainfall variation of selected tahsils of Nagar district are presented in Table 1. The highest average annual rainfall was observed at Jamkhed tahsil (658 mm) followed by Akola (596 mm), Karjat (568mm), Pathardi (520mm). Whereas, the lowest average rainfall was observed at Parner tahsil (413 mm). Then trends in rainfall were determined by using Mann Kendall method,

Table 1: Annual rainfall variation of selected tahsils of Nagar district

Sr. No.	Name of tahsils	Average rainfall (mm)	SD (mm)	CV (%)
1.	Akole	596	190	31
2.	Jamkhed	658	205	31
3.	Karjat	568	192	33
4.	Kopargaon	440	157	35
5.	Nagar	450	213	47
6.	Newasa	495	171	34
7.	Parner	413	181	43
8.	Pathardi	520	208	39
9.	Rahata	498	177	35
10.	Sangamner	431	131	30
11.	Shevgaon	502	197	39
12.	Shrigonda	414	164	39
13.	Shrirampur	513	184	36
	Average	499.85 mm	182.31	36.31

Sen's slope method, Moving average method and Least square method. If three or more methods showed a particular trend then that was considered for that period and that tahsil.

Comparison of rainfall trends:

In this study, four methods have been used for analysing time series such as Mann Kendall method, Sen's slope method, moving average method and least square method. The purpose of this research was to detect best trend for the time series.

Comparison of trend on monthly basis:

For June:

Monthly rainfall of June was analyses by using four different statistical methods as shown in Fig. 1. It showed that Mann Kendall method didn't exhibit any trend for June month. Sen's slope method, moving average method and Least square method showed increasing trend in Nagar, Pathardi, Newasa, Rahata, Sangamner, Parner and Shrirampur tahsils, whereas decreasing trend in Jamkhed, Shrigonda and Kopargaon tahsils. For Karjat tahsil Sen's slope method showed decreasing trend. Least square method showed decreasing trend for Rahata tahsil.

For July:

Monthly rainfall of July was analyses by using four different statistical methods as shown in Fig. 2. It showed that Mann Kendall method exhibited increasing trend for Shevgaon, Kopargaon, Newasa and Shrirampur tahsils and decreasing trend for Shrigonda tahsil only, whereas it didn't exhibit any trend for Nagar, Jamkhed, Akole, Pathardi, Karjat, Rahata, Sangamner and Parner tahsils. Sen's slope method showed increasing trend for Shevgaon, Kopargaon, Newasa, Nagar, Akole, Pathardi,

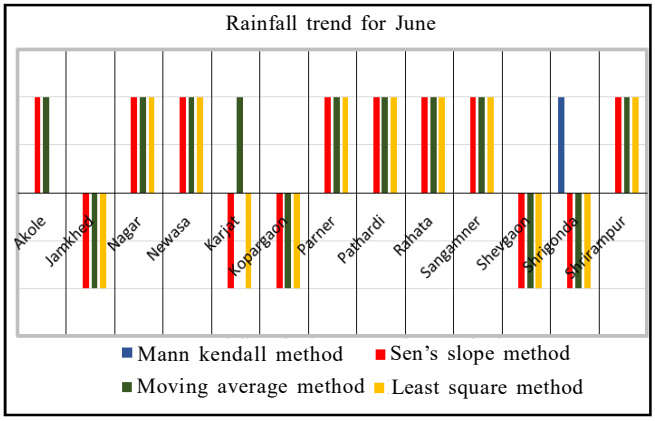

Fig. 1 : Method-wise analysis of rainfall trend for June

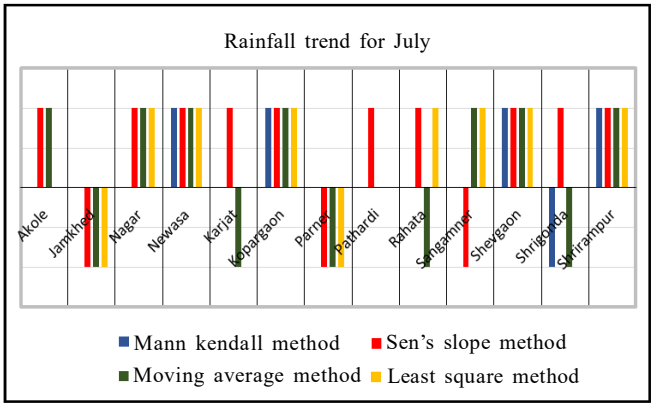

Fig. 2 : Method-wise analysis of rainfall trend for July

Table 2 : Monthly rainfall variation of different tahsils of Nagar district

Tahsil	June			July			August			September			October		
	Mean RF (mm)	CV (%)	SD (mm)	Mean RF (mm)	CV (%)	SD (mm)	Mean RF (mm)	CV (%)	SD (mm)	Mean RF (mm)	CV (%)	SD (mm)	Mean RF (mm)	CV (%)	SD (mm)
Akole	107	67	73	154	50	78	157	82	129	120	59	70	77	97	75
Jamkhed	139	61	86	120	62	75	121	66	81	153	61	94	88	82	73
Karjat	121	63	76	82	80	66	91	73	67	150	72	109	79	82	65
Kopargaon	97	60	58	83	69	57	84	79	67	120	68	82	75	92	70
Nagar	89	73	65	74	83	62	103	70	72	138	79	110	63	93	59
Newasa	97	68	66	93	69	65	105	65	68	138	72	99	63	77	49
Parner	87	88	77	58	70	41	88	71	63	109	80	88	70	68	48
Pathardi	99	78	77	91	88	80	98	62	61	133	71	94	99	96	95
Rahata	113	63	72	93	59	55	89	69	62	11	74	85	87	93	81
Sangamner	96	68	66	77	61	47	64	66	42	124	61	76	58	57	97
Shevgaon	109	72	79	92	67	62	114	86	98	140	65	91	86	75	65
Shrigonda	98	60	59	57	86	49	59	66	39	120	76	92	75	97	73
Shrirampur	92	67	62	94	63	59	100	77	77	136	62	85	95	68	102

Karjat and Rahata tahsils and decreasing trend for Jamkhed, Sangamner and Parner tahsils. Moving average method and Least square method showed increasing trend in Shevgaon, Nagar, Newasa, Sangamner and Shrirampur tahsils, whereas decreasing trend in Jamkhed and Shrirampur tahsils. For Shrigonda, Kopargaon, Karjat and Rahata tahsils Moving average method showed decreasing trend.

For August:

Monthly rainfall of August was analyses by using four different statistical methods as shown in Fig. 3. It showed that Mann Kendall method didn't exhibit any trend for Shevgaon, Jamkhed, Akole, Newasa and Karjat tahsils, whereas it exhibited increasing trend for remaining tahsils. Sen's slope method, moving average method and Least square method showed increasing trend in Shrigonda, Nagar, Jamkhed, Shevgaon, Akole, Pathardi, Newasa, Rahata, Sangamner, Parner and Shrirampur tahsils.

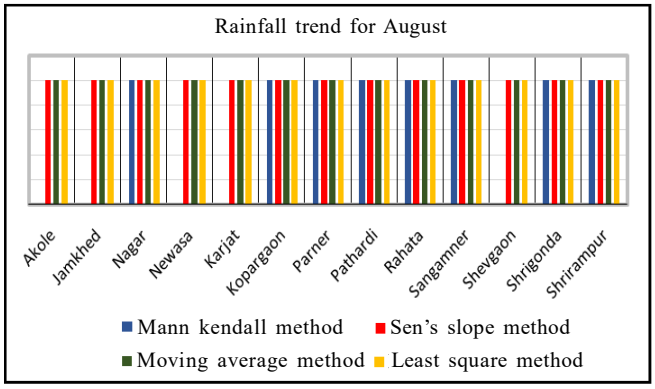

Fig. 3 : Method-wise analysis of rainfall trend for August

For September:

Monthly rainfall of September was analyses by using four different statistical methods as shown in Fig. 4. It showed that Mann Kendall method exhibited increasing trend for only Nagar, Kopargaon, Sangamner and Parner tahsils. Sen's slope method, moving average method and Least square method showed similar increasing trend in Shevgaon, Nagar, Jamkhed, Kopargaon, Akole, Pathardi, Newasa, Rahata, Sangamner, Parner and Shrirampur tahsils, whereas decreasing trend in Shrigonda tahsil.

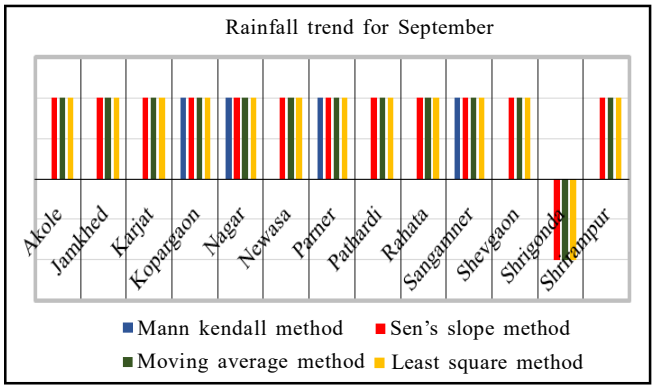

Fig. 4 : Method-wise analysis of rainfall trend for September

For October:

Monthly rainfall of October was analyses by using four different statistical methods as shown in Fig. 5. It showed that Mann Kendall method exhibited increasing trend for only Newasa tahsil and it didn't exhibit any trend for other tahsils. Sen's slope method showed increasing trend for Shevgaon, Nagar, Kopargaon, Akole, Pathardi, Newasa, Rahata, Sangamner, Parner and Shrirampur tahsils, whereas it showed decreasing trend for Jamkhed, Shrigonda and Karjat tahsils. Moving average method didn't exhibit any trend for Rahata and Sangamner tahsils, whereas it showed increasing trend for Kopargaon, Pathardi and Parner tahsils and decreasing trend for Shevgaon, Nagar, Jamkhed, Shrigonda, Akole, Karjat and Shrirampur tahsils. Least square method showed increasing trend in Nagar, Kopargaon, Pathardi, Rahata, Sangamner and Parner tahsils, whereas decreasing trend in Jamkhed, Shrigonda, Newasa and Rahata tahsils. For Karjat tahsil Sen's slope method showed decreasing trend.

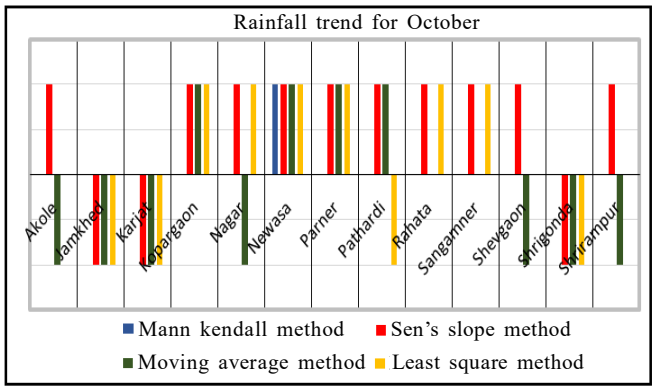

Fig. 5 : Method-wise analysis of rainfall trend for October

Comparison of trend on yearly basis

Yearly rainfall trend was analyzed by using four different statistical methods as shown in Fig. 6. It showed that Mann Kendall method didn't exhibit any trend for

Shevgaon, Jamkhed and Karjat tahsils. Mann Kendall method, Sen's slope method, moving average method and Least square method showed increasing trend in Kopargaon, Akole, Pathardi, Newasa, Rahata, Sangamner, Parner and Shrirampur tahsils. Moving average method showed decreasing trend for Nagar and Shrigonda tahsils. Least square method didn't exhibit any trend for Karjat tahsil, whereas it showed decreasing trend for Kopargaon tahsil.

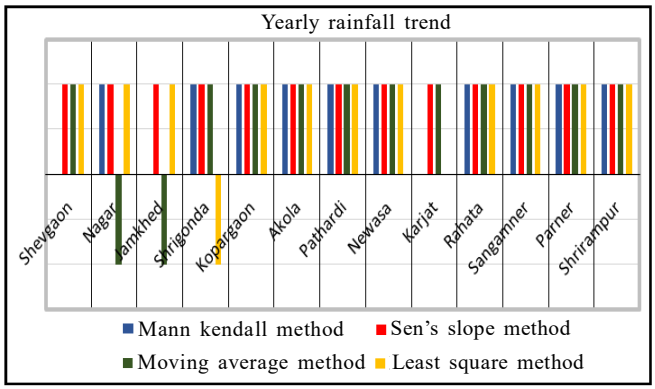

Fig. 6 : Method-wise analysis of annual rainfall trend

Conclusion:

This paper deals with the variability and long-term trends in monthly, seasonal and annual rainfall over Ahmednagar district. It belongs to khandesh and northern maharashtra region. Annual mean precipitation of the study region from 1980-2012 was found to be 499.85 mm. Average seasonal rainfall during *Kharif* season in Ahmednagar district ranges from 413 to 658 mm. July and August months contribute the highest amount of rainfall in all tahsils. The lowest co-efficient of variation (CV) was observed during July followed by August and the highest co-efficient of variation (CV) was observed during October month. Akole, Kopargaon, Nagar, Newasa, Parner, Pathardi, Rahata, Sangamner, Shrigonda, Shrirampur tehsil has increasing trend onannual rainfall while Jamkhed, Karjat and Shevgaon tehsil has no trend.

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