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Trend Analysis of Monthly and Annual Rainfall in Different Tahsils of Ahmednagar District

Pravin N. Jadhav[1*], Vikram Singh[1], Mohd Aftab Alam[2] and Tushar Rathod[1]

[1]Department of Soil and Water Conservation Engineering,
[2]Department of Irrigation and Drainage Engineering, VIAET, SHUATS, Naini, Prayagraj, Uttar Pradesh, India

**Corresponding author*

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ABSTRACT

Accurate prediction of trends in monthly and annual rainfall is an important aspect of climate research and we believe that present study could provide a scope to correlate between current rainfall trend and climate change scenario of the study area. In the present study secular changes in the monthly and annual rainfall of 14tahsils for the period of 23 years from 1998 – 2020 in Ahmednagar, Maharashtra have been studied. 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. Then the rate of change was estimated with the help of Sen's slope test. The slope of the trend indicates the rate and direction of change. The results of the trends were tested at 90, 95 and 99 percent confidence levels for significance. Then trend is also calculated by Moving average and Least square method and it is compared with the Mann Kendall method. There are many types of Trends, the trend may be increasing or decreasing at various time interval. These variables are observed over a long period of time and any changes related to time or noted and calculated and a Trend of these changes is established. Some remain relatively constant and reverse from growth to decline or from decline to growth over a period of time. A change in these conditions would affect the forecast we present various test to detect the best suitable trend for the rainfall time series. The lowest coefficient of variation (CV) was observed during July and the highest coefficient of variation (CV) was observed during October month.

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. 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. The south-west monsoon, which brings about 80% of the total precipitation over the country, is critical for the availability of freshwater for drinking and irrigation. The heavy concentration of rainfall in the monsoon months (June–September) results in scarcity of water in many parts of the country during the non-monsoon periods. 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. The poor precipitation during growth period results in stunted plant growth. Heavy rainfall during early growth period causes submersion of plants (Awasthi *et al.,* 2013).

India being an agrarian economy, where 70 percent of the population depends on agriculture, is highly vulnerable to the impacts of climate risks. The semi-arid regions of Western India are expected to receive higher than normal rainfall as temperature rises. 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).

Maharashtra state is one of the important states from the point view of climate change impact. The geographical area of Maharashtra state is 30.7 Mha of which, 22.5 Mha is cultivable, 40 per cent drought prone and 7 per cent flood prone. A highly variable rainfall ranging from 400 to 4500 mm occurs from 40 to 100 rainy days in the State. Annual availability of water resources consists of 16.4 Mha-m surface water and 2.05 Mha-m as subsurface water.

Geographically, Ahmednagar district is the largest district in the state of Maharashtra. The total geographical area of the district is 17.02 lakh hectares. It is divided into 14 tahsils with a total of 1585 villages. The total population of the district is 40.88 lakhs, out of which 84.2 percent is in rural areas. The district of Ahmednagar is situated in the central part of the state, the location of the district on 18º2' N to 19º9' N latitude and on 73º9' E to 75º5' E longitude. The maximum temperature is around 40° C and minimum temperature is around 11° C. The district receives an average annual rainfall of 566 mm.

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.

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, i.e., Akole, Jamkhed, Karjat, Kopargaon, Nagar, Newasa, Parner, Pathardi, Rahata, Rahuri, Sangamner, Shevgaon, Shrigonda and Shrirampur which will be useful for forecasting the future temporal and spatial availability of water. The aim is to study rainfall variation at 14 tahsils of Ahmednagar district by using various statistical parameters and to analyze the trend in the monthly and annual rainfall data at different tahsils in Ahmednagar district by using different methods.

Materials and Methods

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 Bhima basin. It lies between 18.2º to 19.9º North latitude and 73.9º to 57.5º East longitude. Agro climatically, the district falls in drought prone area. The average rainfall of the district is between 566 mm.

Location Map of Ahmednagar District

A map of the district showing the taluka boundaries as presented in Fig.1.

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).

Statistically trend is a significant change over time which is detectable by various statistical methods, while trend analysis of a time series consists of the magnitude of trend and its statistical significance.

In this study trend analysis will be done by using Mann Kendall method, Sen's slope method, Moving average method and Least square method.

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 Coefficient of variation.

Mann Kendall Test (M-K)

The method tests whether there is a trend in the time series data. For time series with less than 10 data points the S test will be used, and for time series with 10 or more data points the normal approximation (Z) will be 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*.

Let x_1, x_2 …xn represent n data points where x_j represents the data point at time j and x_k represent the data point at time k. Then the Mann Kendall statistic (S) is given by the following formula.

The test statistic *S*, is defined as follows

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

Where, sign (θ) = 1 if θ > 0; sign (θ) = 0 if θ = 0; and sign (θ) = -1 if θ < 0. When $n \geq 10$, the statistic S is approximately normally distributed with the mean and the variance as follows:

$$E[S]=0 \quad \ldots (2)$$

$$VAR(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{q} t_p(t_p-1)(2t_p+5)\right] \quad \ldots (3)$$

Where, t is the extent of any given tie (number of xs involved in a given tie), and $\sum t$ denotes the sum of the terms *t(t-1)(2t+5),* which are evaluated and summed for each tie of the *t* number in the data. The standard normal variable Z is computed by:

$$Z = \begin{cases} \frac{S-1}{\sqrt{VAR(S)}} & if \quad S > 0 \\ 0 & if \quad S = 0 \\ \frac{S+1}{\sqrt{VAR(S)}} & if \quad S < 0 \end{cases} \quad \ldots (4)$$

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 will be calculated

$$Q_t = \frac{x_j - x_k}{j-k}, i = 1,2,3 \ldots N, j > k \quad \ldots (5)$$

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

$$Qt = \begin{Bmatrix} Q_{\frac{N+1}{2}} & if\ N\ is\ odd \\ \frac{1}{2}\left(Q_{\frac{N}{2}} + Q_{\frac{N+2}{2}}\right) & if\ N\ is\ even \end{Bmatrix} \quad \ldots (6)$$

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. 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 (Yogish, 2007).

Least Square Method

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).

The equation of a straight line is

$$y=a+bx \quad \ldots (7)$$

Where y is the dependent variable, a and b are two unknown constants whose values are determined by solving two normal equations and x is the unit of time. Two normal equations are used to find the values of the constants a and b.

They are

$$\sum y=na+b\sum x \quad \ldots (8)$$

$$\sum xy=a\sum x=b\sum x^2 \quad \ldots (9)$$

The trend line obtained for the equation, y= a + bx can be used for prediction of y value for the required year x.

Results and Discussion

Statistical Analysis of Rainfall Data of 14 Tahsils

The statistical parameters viz. mean, standard deviation and coefficient of variation were determined. The coefficient of variation during different months for different tahsils are presented in Table 1. Which showed that the lowest coefficient of variation (CV) was observed during July followed by August and the highest coefficient of variation (CV) was observed during October month.

Table.1 Coefficient of variation for rainfall during different months and annual rainfall at different tahsils in Ahmednagar district

Month Tahsil	June	July	August	September	October	Annual
Akola	56	55	63	57	78	29
Jamkhed	55	71	61	56	74	33
Karjat	64	60	70	66	77	33
Kopargaon	60	59	53	56	87	29
Nagar	94	100	63	161	147	99
Newasa	56	65	65	48	82	31
Parner	68	64	55	55	71	36
Pathardi	50	88	68	58	98	34
Rahata	63	56	48	56	89	32
Rahuri	74	54	60	65	80	31
Sangamner	66	51	55	44	81	24
Shevgaon	54	76	70	54	86	33
Shrigonda	64	70	74	58	71	38
Shrirampur	115	87	63	95	172	84

Fig.1 Study area showing location of 14 tahsils

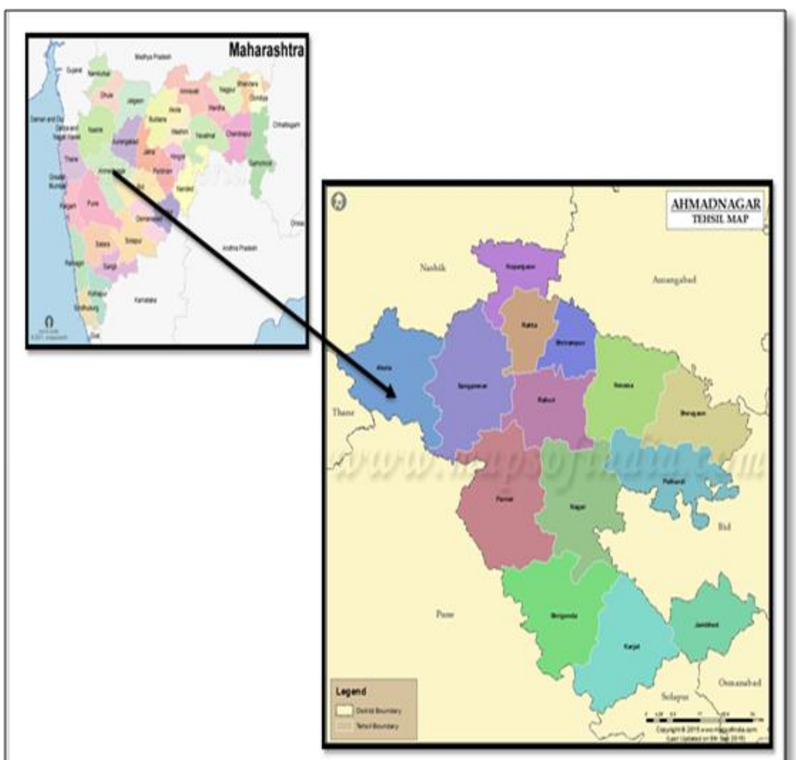


Table.2 Monthly and Annual trend analysis values of Mann Kendall Method (Z Statistic) and Sens Slope Method (Q Statistic) Year:1998 to 2020 N:23

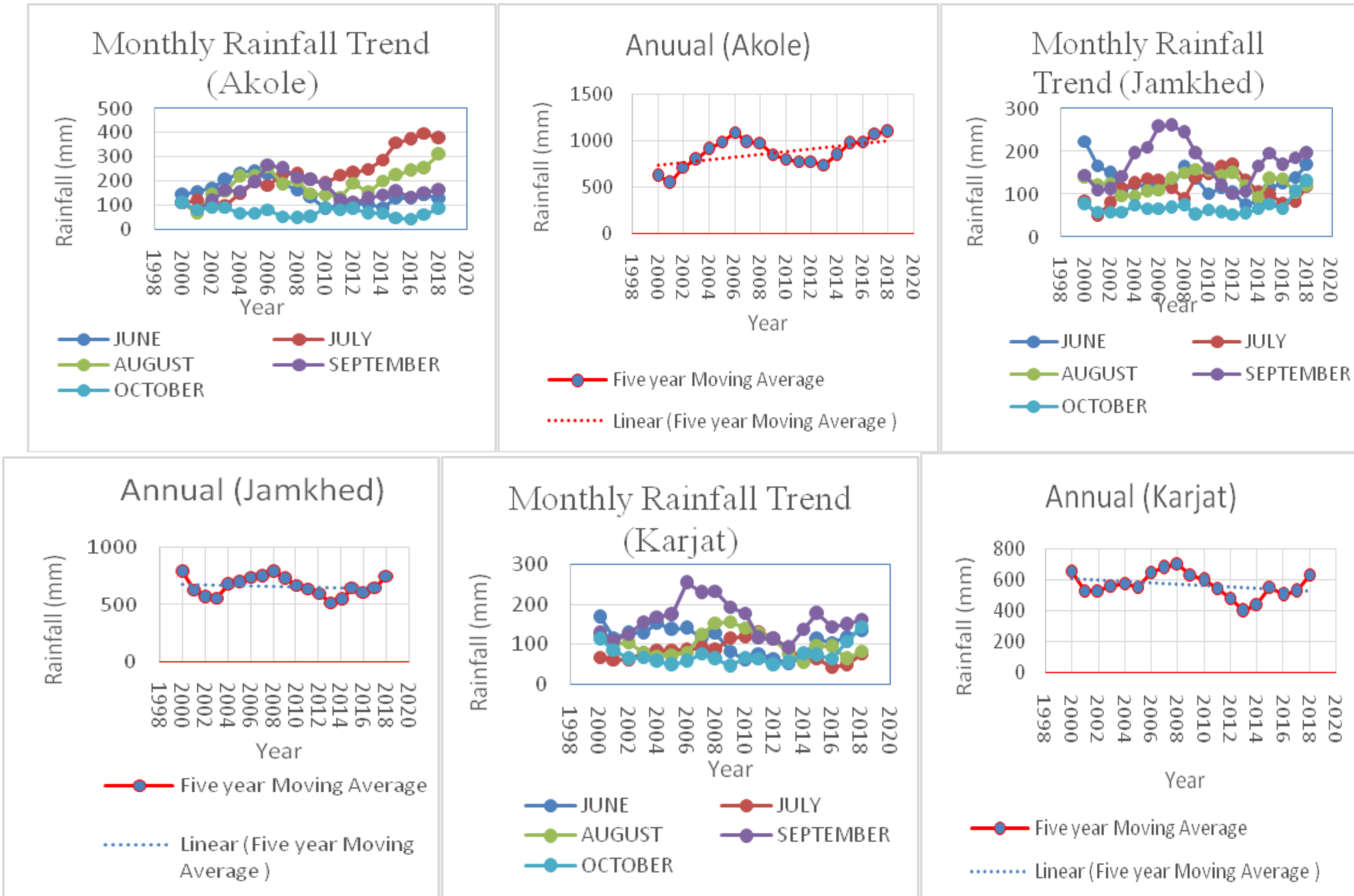
Time series / Tahsils	June		July		August		September		October		Annule	
	Test Z	**Q**	**Test Z**	**Q**	**Test Z**	**Q**	**Test Z**	**Q**	**Test Z**	**Q**	**Test Z**	**Q**
Akole	-0.5282	-1.65	3.1164**	13.035	1.9544+	9.000	0.6339	1.879	0.0793	0.200	1.5318	17.42
Jamkhed	-0.6867	-2.14	0.6339	1.68	-0.6077	-2.000	0.0528	0.431	1.0564	1.083	-0.1585	-1.000
Karjat	-0.7923	-2.089	-0.1057	-0.400	-0.898	-2.506	-0.3169	-0.531	0.1585	0.400	-0.4754	-4.353
Kopargaon	0.2113	0.556	1.4262	3.165	-0.1849	-0.714	0.3963	1.141	0.6343	0.829	0.4226	2.367
Nagar	-0.3169	-1.029	0.4226	1.213	-0.1321	-0.875	-0.1849	-0.788	-0.6077	-0.842	-0.2641	-2.889
Newasa	-0.1056	-0.195	1.2946	2.625	0.6867	1.700	0.7923	2.400	-0.2643	-0.800	0.6867	5.050
Parner	0.1585	0.445	-0.1056	-0.091	-1.9286+	-3.146	-0.1585	-0.500	0.4491	1.077	0.0000	-0.443
Pathardi	-0.8718	-1.595	0.0528	0.677	-0.7923	-3.450	0.7133	2.440	0.2643	0.542	-0.5282	-2.300
Rahata	0.3697	0.894	1.2149	1.180	-1.1092	-1.970	0.4491	1.517	0.2649	0.571	0.1056	1.950
Rahuri	0.2906	0.969	0.1849	0.286	0.1849	0.250	-0.2113	-1.017	-0.0264	0.000	-0.6867	-5.361
Sangamner	-0.8451	-1.467	2.1657*	3.414	0.2906	0.333	-1.0832	-1.471	-0.2906	-0.720	-0.2641	-0.825
Shevgaon	-0.4754	-1.600	0.1585	0.536	-0.2641	-0.545	0.3435	1.000	-0.1851	-0.380	-0.4226	-5.346
Shrigonda	0.0000	0.000	-0.1056	-0.200	-1.136	-3.025	-0.2641	-1.225	0.6077	1.677	-0.4491	-4.500
Shrirampur	-0.9775	-1.647	0.8986	1.667	-0.6605	-1.331	0.0000	0.000	-0.2113	-0.372	-0.2641	-3.000

**Significance at 99 percent confidence level, *Significance at 95 percent confidence level and + Significance at 90 percent confidence level

Table.3 Tahsil wise Values of Least square method

Time series Tahsils	June		July		August		September		October		Annule	
	Slope	**Intercept**	**Slope**	**Intercept**	**Slope**	**Intercept**	**Slope**	**Intercept**	**Slope**	**Intercept**	**Slope**	**Intercept**
Akole	-2.3184	177	12.485	79.511	7.7318	101.31	0.7293	151.83	-1.4001	98.401	16.476	676.33
Jamkhed	-2.7768	178.25	0.5107	110.38	-1.0757	139.01	-0.1607	173.93	2.1569	53.726	-6.8282	776.92
Karjat	-2.7746	151.33	-0.0326	85.448	-1.7862	123.3	-0.7087	165.55	1.8394	65.588	-4.4844	641.44
Kopargaon	0.7177	85.392	2.5815	56.796	-1.1015	105.58	1.1413	106.42	-0.2319	63.04	3.2285	448.08
Nagar	-4.4501	194.59	-3.3045	144.89	-0.7134	122.32	-16.347	425.63	-6.0392	168.48	-30.612	1074.4
Newasa	1.0126	86.657	2.9066	68.125	0.8239	109.92	2.249	120.39	0.261	64.068	7.5747	470.01
Parner	-0.0568	107.14	0.4674	66.665	-2.653	120.64	0.6139	130.8	0.1044	70.686	-1.3467	519.87
Pathardi	-2.029	150.88	0.87	80.143	-2.4984	148.09	2.3519	126.99	-0.6279	98.152	-3.8686	663.92
Rahata	1.2168	105.46	1.5812	66.175	-2.2892	130.62	1.5359	116.46	1.5041	38.501	3.847	477.1
Rahuri	0.7152	98.583	1.6126	71.396	0.0487	106.98	-2.3243	203.57	-0.7085	78.332	-1.7519	607.39
Sangamner	-2.2976	129.15	3.09	46.472	0.8946	77.943	-1.897	159.89	0.3554	54.809	-0.4488	520.13
Shevgaon	-0.427	120.57	2.7774	61.628	-0.3231	123.89	1.3572	138.7	-0.9197	86.71	1.5744	573.37
Shrigonda	0.089	103.11	0.2685	71.783	-2.2961	113.98	-0.86	160.58	1.0735	69.166	-3.742	576.7
Shrirampur	-6.7146	212.26	-1.2611	133.76	-2.0458	148.85	-5.8756	250.69	-8.7381	213.94	-24.916	996.69

Fig.2 Monthly and Annual trend Analysis of Akole, Jamkhed, Karjat, Kopargaon, Nagar and Newasa Tahsils by Moving Average Method



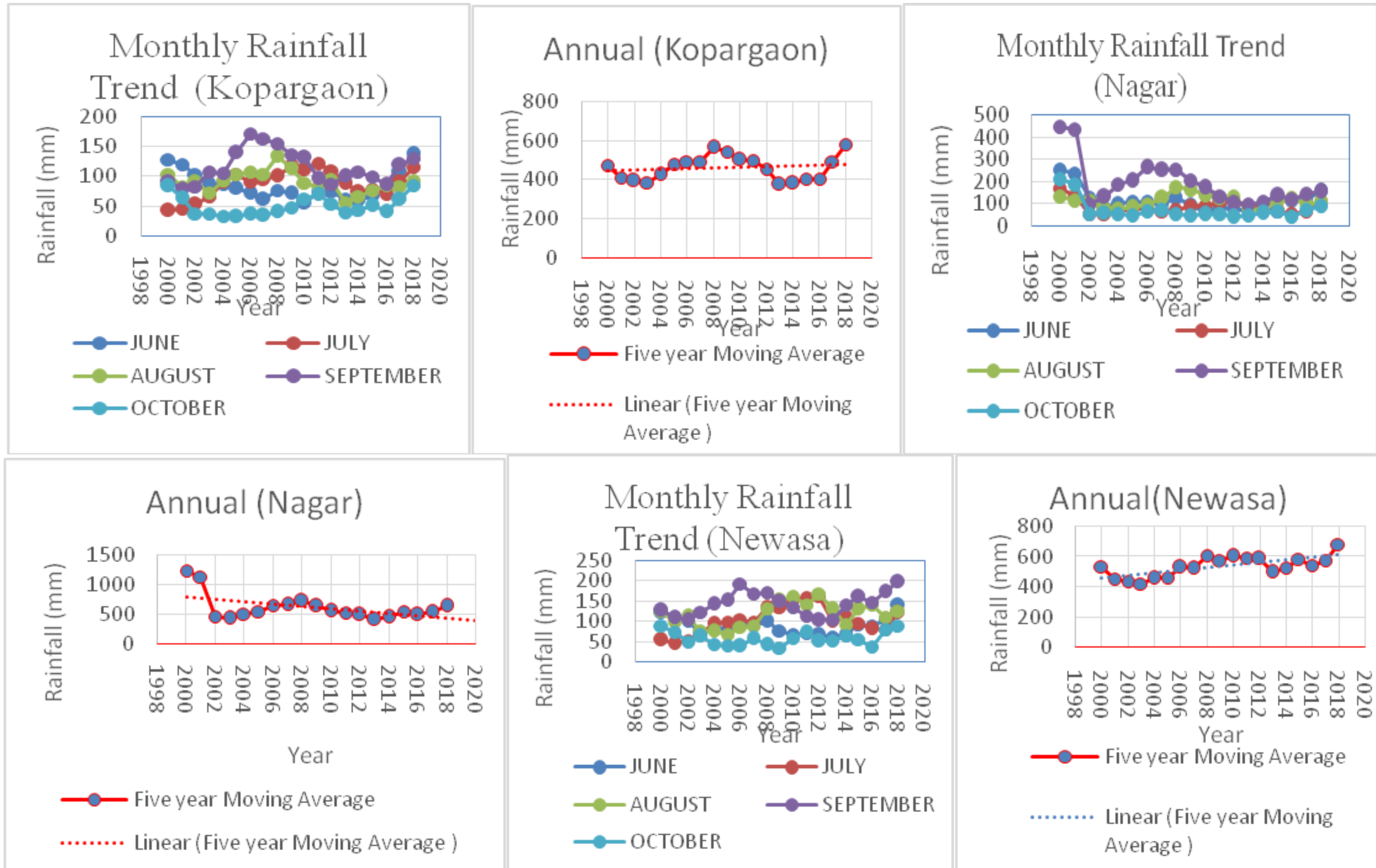
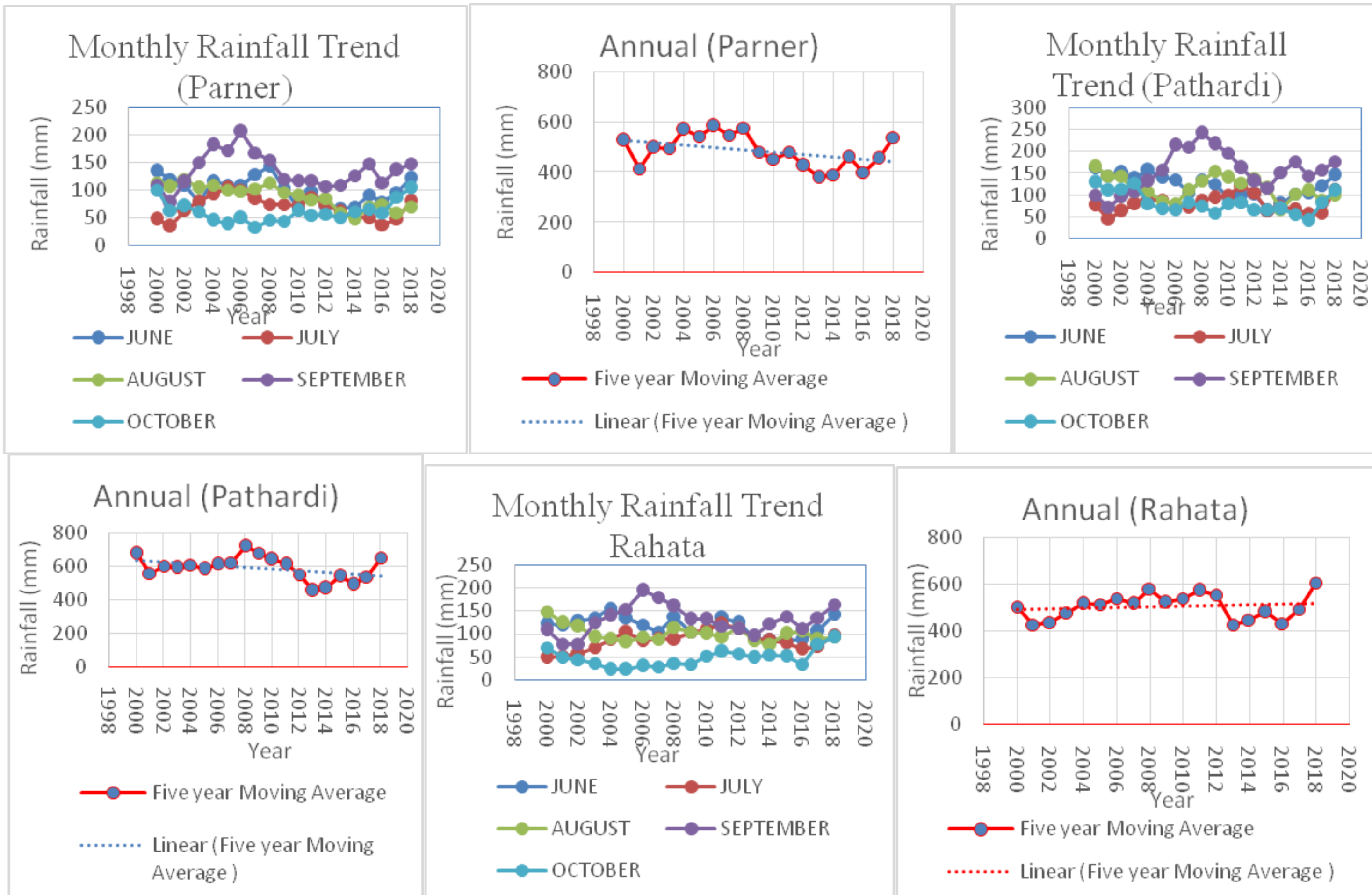

Monthly Rainfall Trend (Kopargaon)
Rainfall (mm)
Year
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
Annual (Kopargaon)
Rainfall (mm)
Year
Five year Moving Average
Linear (Five year Moving Average)
Monthly Rainfall Trend (Nagar)
Rainfall (mm)
Year
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
Annual (Nagar)
Rainfall (mm)
Year
Five year Moving Average
Linear (Five year Moving Average)
Monthly Rainfall Trend (Newasa)
Rainfall (mm)
Year
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
Annual(Newasa)
Rainfall (mm)
Year
Five year Moving Average
Linear (Five year Moving Average)

Fig.3 Monthly and Annual trend Analysis of Parner, Patardi, Rahata, Rahuri, Sangamner and Shevgaon Tahsil by Moving Average Method



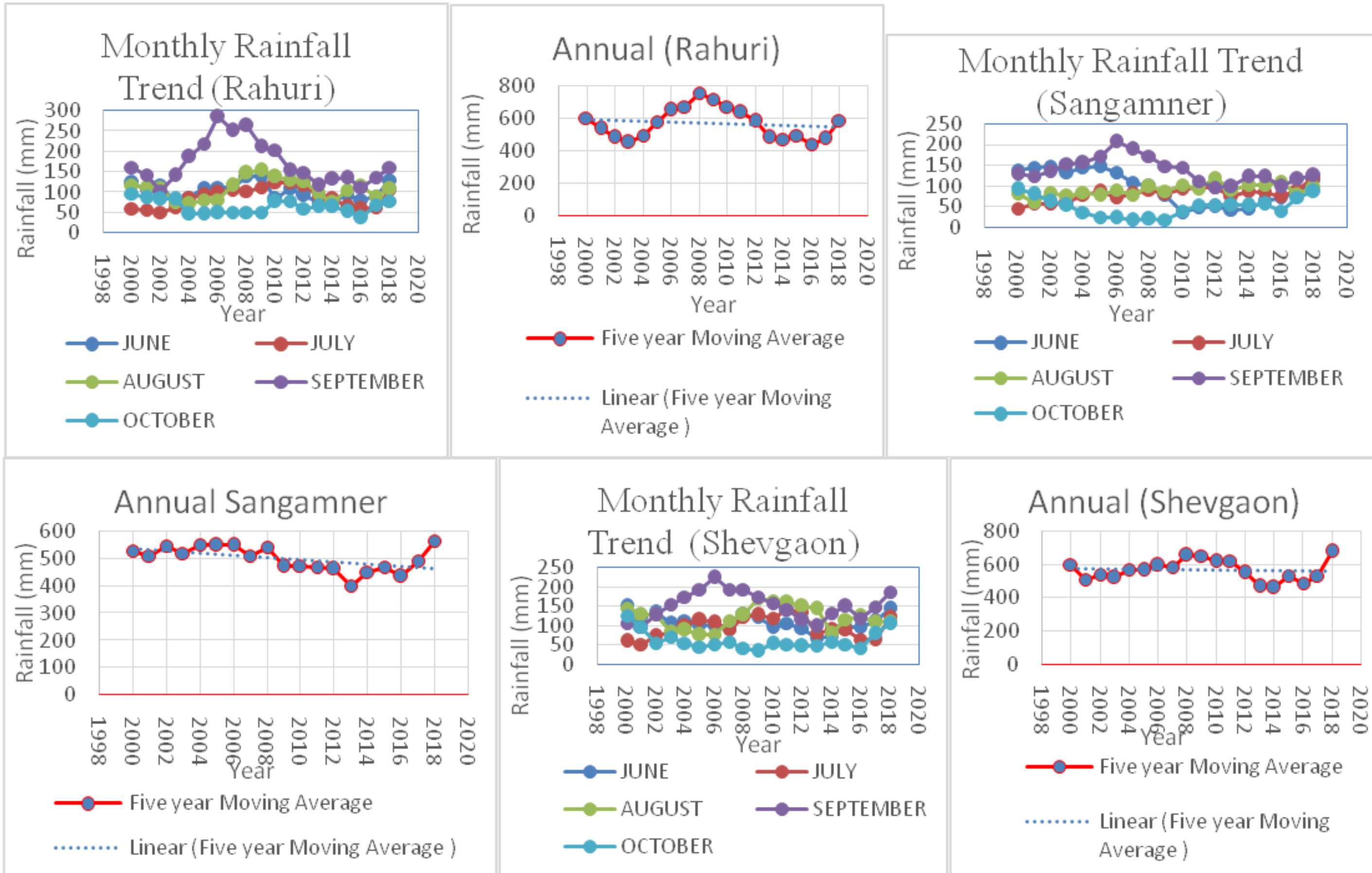

Monthly Rainfall Trend (Rahuri)
Rainfall (mm)
Year
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
Annual (Rahuri)
Rainfall (mm)
Year
Five year Moving Average
Linear (Five year Moving Average)
Monthly Rainfall Trend (Sangamner)
Rainfall (mm)
Year
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
Annual Sangamner
Rainfall (mm)
Year
Five year Moving Average
Linear (Five year Moving Average)
Monthly Rainfall Trend (Shevgaon)
Rainfall (mm)
Year
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
Annual (Shevgaon)
Rainfall (mm)
Year
Five year Moving Average
Linear (Five year Moving Average)

Fig.4 Monthly and Annule trend Analysis of Parner, Patardi, Rahata, Rahuri, Sangamner and Shevgaon Tahsils by Moving Average Method

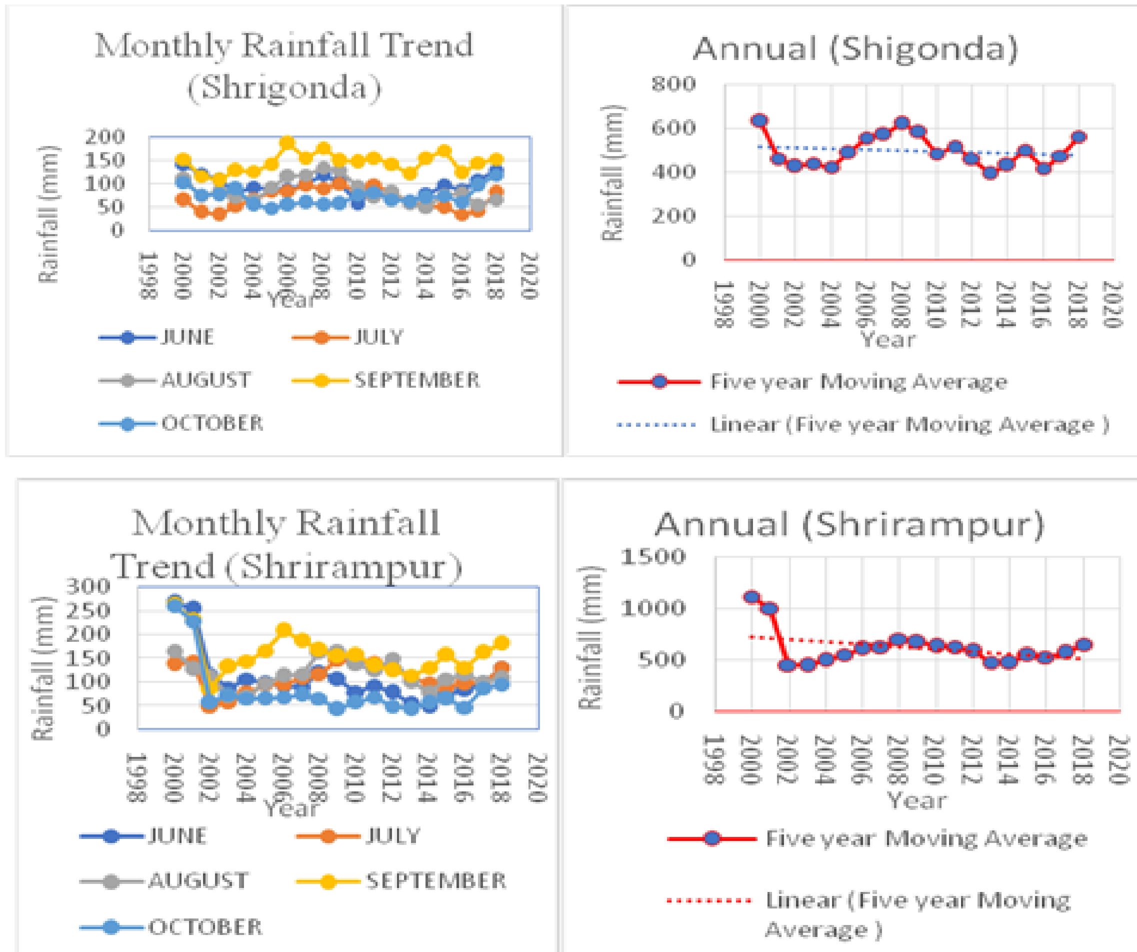
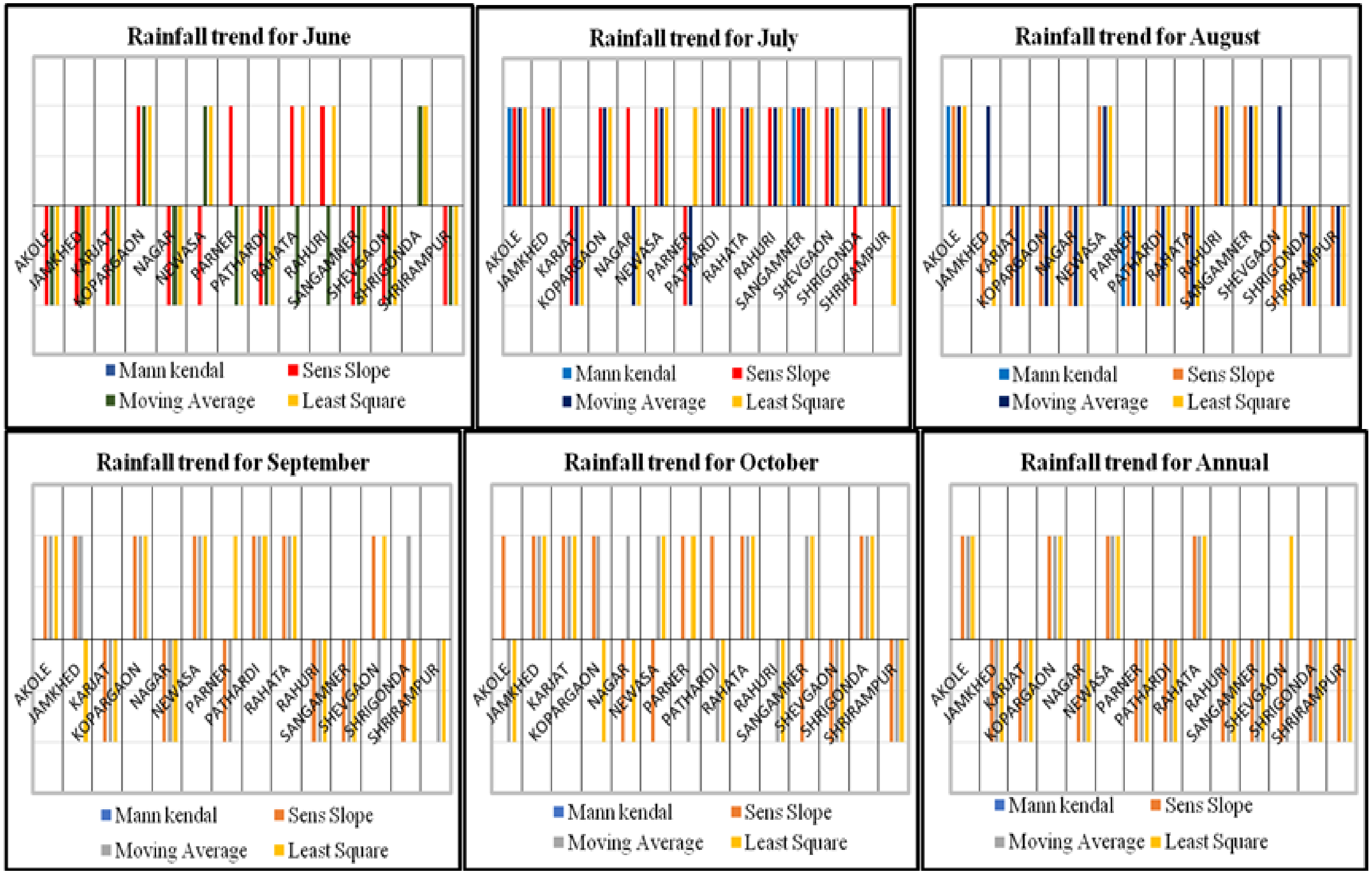


Fig.5 Comparison of Trend on Monthly and Yearly Basis



Rainfall Trends

The annual rainfall series in respect of 14 raingauge stations were tested for the presence of trends by applying the Mann Kendall method, Sen's slope method, Moving average Method and Least squares method.

Trend analysis by Mann Kendall Method and Sen's Slope Method

The Mann Kendall trend, its statistical significance along with magnitude of Sen's slope for 1998 to 2020 year rainfall data is shown in Table 2. The test results showed that annual rainfall of 14 tahsils over the 23 years didn't exhibit any statistical significant trend at the significance level of 90 percent, 95 percent and 99 percent. The trend was significant increasing for July month (Z= 3.1164) at 99 percent confidence level and for Aug month (Z= 1.9544) at 90percent confidence level in Akole Tahsil.

The trend was significant decreasing for August month (Z= -1.9286) at 90 percent confidence level in Parner Tahsil. The trend was significant increasing for July month (Z= 2.1657) at 95 percent confidence level in Sangamner Tahsil.

Trend analysis by Moving average Method

The monthly and annule rainfall trends were estimated by five year moving average method at different tahsils were presented in Fig.2, 3 and 4 which Showed that for the selected tahsil the monthly rainfall received during month of October was less than the other months and for other months the monthly rainfall received in the month July, August and September was more than the other months for the whole of the time period considered for the study. Annual trend is increasing in Akole, Kopargaon, Newasa and Rahata tahsil and decreasing for all other tahsils.

Trend analysis by Least Square Method

The values of the slope and the intercepts for monthly and annual trend were presented in table 3. The slope coefficient indicates the rate of change in the rainfall characteristic. The sign of the slope defines the direction of the trend of the variable, if sign is positive then it has increasing trend and if sign is negative then it has decreasing trend.

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. The comparison of rainfall trend according to four methods for monthly and annual was presented in Fig.5 which showed that Sen's slope method, Moving average method and Least square method mostly showed common results.

The following conclusions were drawn based on the results of study:

July and August months contribute the highest amount of rainfall in all tahsils. The lowest coefficient of variation (CV) was observed during July followed by August and the highest coefficient of variation (CV) was observed during October month.

Trend analysis of rainfall data at various tahsils showed results as follows,

During the time span 1998-2020, an increasing trend has been found in the monthly rainfall for the months July, September and October in Akole tahsil, for the month of July, August and September in Jamkhed Tahsil, for the month of October in Karjat and Parner tahsils, for the month of June, July, September and October in

Kopargaon and Rahata tahsils, for the month of June, July, August, September and October in Newasa Tahsil, for the month of July and September in Pathatdi and Shevgaon Tahsils, for the month of June, July and August in Rahuri tahsil, for the month of July, August and October in Sangamner Tahsil, for the month of June, July and October in Shrigonda tahsil, for the month of July in Shrirampur tahsil.

During the time span 1998-2020, an decreasing trend has been found in the monthly rainfall for the months June and August. In Akole tahsil, for the month of June and October in Jamkhed Tahsil, for the months of June, July, August and September in Karjat and Parner Tahsils, for the month of August in Kopargaon and Rahata tahsils, for the month of June, July, August, September and October in Nagar Tahsil, for the month of June, August and October in Pathatdi and Shevgaon Tahsils, for the month of September and October in Rahuri tahsil, for the month of June and September in Sangamner Tahsil, for the month of August and September in Shrigonda tahsil, for the month of June, August, September and October in Shrirampur tahsil.

During the time span 1998-2020, an increasing Annual rainfall trend has been found only in the the tahsils Akole, Kopargaon, Newasa and Rahata.

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