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Rainfall Trend Analysis in Tehsils of Palghar District, Maharashtra State, India

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Abstract: ***A detailed trend analysis of monthly and annual rainfall for Tehsils of Palghar district were carried out using 22 years (1998-2019) daily rainfall data taken from Department of Agriculture, Maharashtra State. In this study, to analyse the trend, the non-parametric test (Mann-Kendall test) and Sen's slope estimator were used. For developing a functional relationship between variables, a linear trend of rainfall data for the studied area evaluated using the linear regression. The results showed that the trend analysis of monthly rainfall has a varied trend of rainfall in the rainy months in tehsil of Palghar District. The month of July significant increasing trend was observed at Jawhar (42.91 mm/year), Vikramgad (29.90 mm/year), Wada (24.06 mm/year), Talasari (31.36 mm/year), Palghar (25.299 mm/year), Mokhada (29.96 mm/year) and Dahanu (38.14 mm/year), whereas non-significant increasing trend 2.76 mm/year was observed at Vasai tehsil of Palghar District during 1998-2019. The month of June, August, September and October rainfall did not show any significant trend in tehsil of Palghar District and non significant decreasing as well as non significant increasing trend was observed in tehsil of Palghar District during 1998 – 2019. The result concluded that annual rainfall trend was increased in Jawhar, Vikramgad, Wada, Talasari, Palghar, Mokhada and Dahanu; whereas Vasai tehsil rainfall trend was decreased in tehsil of Palghar District during 1998 -2019.***

Keywords: Rainfall, Trend Analysis, Mann Kendall's Test, Sen Slopes, Regression

I. INTRODUCTION

Rainfall is one of the vital climatic factors that can indicate climate change. The variation of rainfall would affect the hydrological properties and soil characteristics. The trend analysis of rainfall data is important in studying the influences of climate change for planning and management of water resources.

Understanding rainfall variability is essential to optimally manage the scarce water resources that are under continuous stress due to the increasing water demands, increase in population, and the economic development (Herath and Ratnayake, 2004). The changing pattern of rainfall is a topic within this field that deserves urgent and systematic attention, since it affects both the availability of freshwater and food production (Dore, 2005).

Rainfall patterns decide the cropping pattern sustainability and productivity of agriculture plan. The intensity and frequency of rainfall can be considered a condition for standard of human living. The knowledge about rainfall probability allows us to manage with the severe conditions faced during the season (Kumar et al. 2015). In many countries worldwide, the agriculture continues depends to the chance of occurring of rainfall, and nearly 70% of the net sown area is still depending on the rain (Narain et al. 2006). Many studies have conducted in recent years to study trends around the world, see (Khan et al., 2000; Shrestha et al., 2000; Mirza, 2002), finding that the frequency of intense rainfall has increased in many parts of Asia, but the number of rainy days and total annual rainfall has decreased. From the studies of different types of time series data, it has been found that, the trend of time series of hydrological parameters is varying significantly (i.e. increasing, decreasing and remain as the origin).

Wing Cheung et al. (2008) found a significant decline in June to September (i.e. Kiremt) rainfall for the Baro-Akobo, Omo-Ghibe, Rift Valley, and Southern Blue Nile watersheds located in the south-western and central parts of Ethiopia. Kumar et al. (2010) studied monthly, seasonal and annual trends of rainfall have been studied using monthly data series of 135 years (1871-2005) for 30 sub-divisions (sub-regions) in India. Half of the sub-divisions showed an increasing trend in annual rainfall, but for only three (Haryana, Punjab and Coastal Karnataka), this trend was statistically significant. Similarly, only one sub-division (Chhattisgarh) indicated a significant decreasing trend out of the 15 sub-divisions showing decreasing trend in annual rainfall. Jain et al. (2012) reported that rainfall has no any clear trend for the region as a whole, although there are seasonal trends for some seasons and for some hydro-meteorological subdivisions of Northeast India.

No such a work was reported for tehsils of Palghar districts; therefore present research study was undertaken to know about rainfall trend in tehsils of Palghar districts. To know about rainfall trend in tehsils of Palghar districts is very essential and important for to predict the influence of climate change.

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II. MATERIALS AND METHODS

A. *Study Area*

Palghar district is situated between 19° 17' N and 20° 14' N latitude and 72° 39' E and 72° 31' E longitude. The total geographical area of Palghar district is 5,344 sq. km. The average ambient temperature remains 27.3 ^{o}C, varies from 17.1 ^{o}C to 36.4 ^{o}C. The average relative humidity remains around 70.4 %, varies 26.9 % to 97.1 %. Tehsils of Palghar districts namely Vasai, Jawhar, Vikramgad, Wada, Talasari, Palghar, Mokhada and Dahanu were selected as study area.

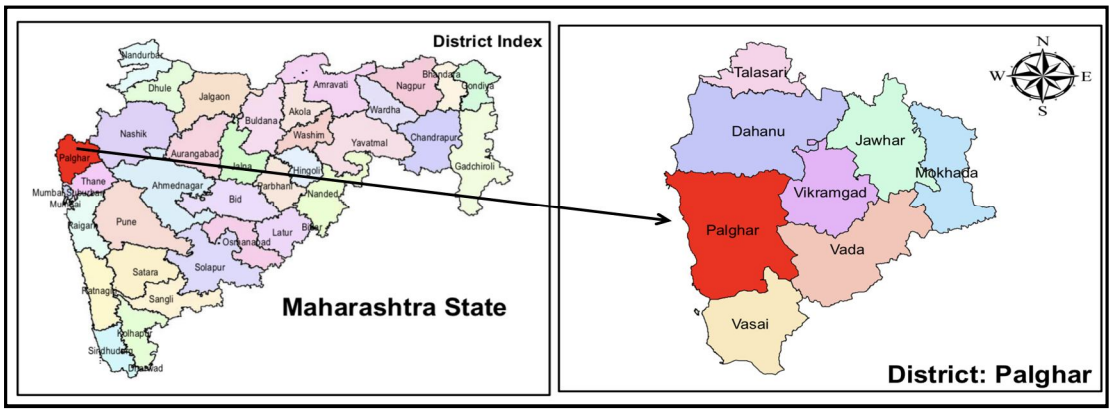


Figure 1: Location Map of Study Area

B. *Data Collection*

The daily rainfall data of eight tehsils viz. Vasai, Jawhar, Vikramgad, Wada, Talasari, Palghar, Mokhada and Dahanu of Palghar Districts were taken from Department of Agriculture, Maharashtra State (maharain.maharashtra.gov.in) for period of 1998 – 2019.

C. *Methodology*

The daily rainfall (tehsil-wise) data for a period of 22 years (1998 – 2019) were converted into monthly and annual rainfall. These 22 years data was future used for the rainfall trend analysis such as Kendall's Tau, S Statistics, Sen Slope estimator, mean rainfall, standard deviation and coefficient of variation. For the months November to May for a all data has been neglected due to there was no rainfall or very less rain occur in this months and all statistical parameter near zero in tehsil of Palghar District during period of 22 years (1998 – 2019). In this research study monsoon season (rainfall contribution ranges from 95.5 % to 97.0 %) months June, July, August and September and one month of Post Monsoon season October (rainfall contribution ranges from 2 % to 4 %) month was considered for monthly trend analysis.

D. *Rainfall Analysis Trend*

For several years, the researchers and hydrologists are interested in trend analysis of meteorological variables such as rainfall, temperature, relative humidity, wind velocity, and stream flow. The preceding studies suggested the non-parametric Mann-Kendall test is the most widely used method. Trend analysis of the selected area for rainfall is carried out in this study, firstly by checking the trend whether the Mann-Kendall (non-parametric) test for both annual and monthly average rainfall data series decreases, increases or no trends. Then second step, estimating the magnitude of trend using the Sen's slope estimator. Finally, in the third step a regression model was developed for the observation rainfall data. Below the details of the three steps for trend analysis

E. *Test of Mann-Kendall trend*

The non-parametric (Mann-Kendall) test (Kendall, 1975; Mann, 1945), due to its insensitivity to the normal distribution of data time series and outliers, this statistical model is mostly used for patterns identifying in hydro-meteorological data time series. The statistics of the Mann-Kendall test (S) are given below:

$$S = \sum_{j-1}^{n-1} \sum_{n-j-1}^{n} sign\,(X_j - X_i) \qquad \ldots (1)$$

where,

n = numbers of data points

Xj and Xi are annual values in years j and i, j > 1

Sign (Xj – Xi) calculated using the equation:

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$$\text{Sign (Xj – Xi)} = \begin{cases} -1 \; for \; \text{Sign}\,(X_j - X_i) < 0 \\ 0 \; for \; \text{Sign}\,(X_j - X_i) = 0 \\ +1 \; for \; \text{Sign}\,(X_j - X_i) > 0 \end{cases} \quad \dots (2)$$

Sign (Xj – Xi) means the individual sign capability that takes on the values [1, 0, or -1]. A positive S value indicates an ever-increasing trend, and a negative value indicates a downward trend. Nevertheless, the statistical analysis for the validity of the phenomenon needs to be carried out. The test procedure using the normal approximation test is described by Kendall (1975). This test assumed that the data set does not contain many connected values. The variance (S) is calculated with the following equation:

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

where,

n = data points number,

g = zero difference between compared values number,

t_p = number of data points in the p^{th} group.

A standardized measure of test statistics (Z_{mk}), determined using the following equation:

$$Z_{mk} = \begin{cases} \frac{S-1}{\sqrt{Var\,(S)}}, if \; S < 1 \\ 0, if \; S = 0 \\ \frac{S+1}{\sqrt{Var\,(S)}}, if \; S > 1 \end{cases} \quad \dots (4)$$

The determined standardized Z_{mk} values follow distribution normal with variance normal “0”and “1”, it is utilized a measure of trend significance. In fact, this test measurement is utilized to null hypothesis test, H_0 if Z_{mk} is more than $Z\alpha/_2$. This value of Z_{mk} is contrasted and standard distribution normal table of two followed test at certainty levels of α = 1 %, α = 5 % and α = 10 %. In a two-followed test, null hypothesis (H_0) is accepted for no trend if the determined value of Z_{mk} between $-Z_1\text{-}\alpha/_2$ and $Z_1\text{-}\alpha/_2$, and in this way, H_1 is rejected.

F. Test of Sen's Slope Estimator

Simple linear regression is one of the most frequently used model for the linear trend identification. This method requires however the assumption of residual normality (McBean and Motiee, 2008). Viessman et al. (1989) stated that, due to the influence of natural phenomena, many hydrological variables show a pronounced right skewed ness and do not adopt a normal distribution. Thus the Sen (1968) slope estimator is found to be a powerful tool to develop the linear relationships. Sen’s slope has the advantage over the slope of regression, in the sense that gross data series errors and outliers do not affect in much. The slope of the Sen was determined to be the mean of all pair-wise slopes for any pair of points in the dataset. The following equation is used to estimate each individual slope (m_{ij}):

$$m_{ij} = \frac{(Y_j - Y_i)}{j-1} \quad \dots (5)$$

where, i = 1 to n - 1, j = 2 to n, Yj and Yi are data values at time j and i (j > i), respectively

If in the time series there are n values of Yj, estimates of the slope will be N= n (n-2)/2. The slope of the Sen Estimator is the mean slope of such slopes N values. The Sen's slope is:

$$m = \begin{cases} m_{\left[\frac{N+1}{2}\right]} & if \; n \; is \; Odd \\ \frac{1}{2}\left(m_{\frac{N}{2}} + m_{\left[\frac{N+2}{2}\right]}\right) & if \; n \; is \; even \end{cases} \quad \dots (6)$$

Positive Sen's slope reveals an upward trend while negative Sen’s slope suggests a downward trend.

G. Linear Regression Analysis

Linear regression analysis is a parametric model and one of the most common methods to detect a pattern in data series. By fitting a linear equation to the observed data, this model establishes a relationship between two variables (dependent and independent). Next, the data is tested there is to find out whether there is a relationship between the interest variables or not. This is possible with the scatter plot. If no relationship between the two exists variables, the linear regression model does not prove to be a useful model. The correlation coefficient which ranges from -1 to +1 is a numerical measure of this correlation between the variables. A coefficient value ± 1 for correlation indicates a good match. A value close to zero implies that the two variables have a random, non-linear relation. The linear regression model is generally described by the following equation

$$Y = \text{m} * X + C \quad \dots (7)$$

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Where, Y and X are the dependent variable (rainfall) and the independent variable (time in months or years), respectively, m is the line slope (mm/year) and C is the intercept constant coefficient. The coefficients (m and C) of the modal are determined using the Least-Squares method, which is the most commonly used method. Slope sign defines trend variable direction; increases if the sign is positive and decreases if the sign is negative.

III. RESULTS AND DISCUSSION

The tehsil-wise monthly and annual rainfall was analysed. The results obtained are discuses below:

A. Tehsil-wise Rainfall Trend Analysis for Month of June (1998-2019)

The mean rainfall in month of June was given in Table 1 for the tehsils of Palghar District. The highest average rainfall 628.9 mm was observed at Vasai with 47.8 % variation and lowest at Mokhada tehsil 405.3 mm with a coefficient of variation 62.0 %. All tehsil receive more than 400 mm rainfall in month of June.

Table 1: Statistical and Mann-Kendall trend analysis of rainfall for month of June during 1998-2019 in tehsils of Palghar district

Tehsils	Mean	SD	CV (%)	Kendall tau (Z)	S Statistics	P value	Significant
Vasai	628.9	300.8	47.8	-0.23	-53.0	0.143	No
Jawhar	406.7	203.5	50.1	-0.14	-33.00	0.367	No
Vikramgad	471.3	257.4	54.6	-0.09	-21.00	0.573	No
Wada	485.9	327.8	67.5	-0.08	-19.00	0.612	No
Talasari	466.8	285.2	61.1	-0.11	-25.00	0.499	No
Palghar	513.1	273.6	53.3	0.06	15.00	0.693	No
Mokhada	405.3	251.2	62.0	-0.26	-61.00	0.091	No
Dahanu	479.1	267.6	55.8	0.02	5.00	0.910	No

The result of the Mann Kendall analysis to detect the trend and magnitude of trend determined Sen Slope's Estimator for the month of June during 1998-2019. The Kendall's tau values of Vasai, Jawhar, Vikramgad, Wada, Talasari, Palghar, Mokhada and Dahanu were -0.23, -0.14, -0.09, -0.01, -0.11, 0.06, -0.26 and 0.02 with Sen's Slope Estimator (Q) -16.02, -8.70, -3.55, -0.33, -7.72, 6.98, -12.36 and 2.74 respectively.

Table 2 Sen's slope estimators and linear regression analysis for month of June during 1998-2019

Tehsil	Sen's Slope (Q)	Trend	Linear Equation	m (mm/year)	R^2
Vasai	-16.02	Decreasing	y = -16.235x + 815.57	-16.24	0.12
Jawhar	-8.70	Decreasing	y = -6.8899x + 485.9	-6.89	0.05
Vikramgad	-3.55	Decreasing	y = -5.6032x + 535.78	-5.60	0.02
Wada	-4.14	Decreasing	y = -9.6226x + 596.57	-9.63	0.04
Talasari	-7.72	Decreasing	y = -6.0233x + 536.1	-6.02	0.02
Palghar	6.98	Increasing	y = 6.2751x + 440.93	6.27	0.02
Mokhada	-12.36	Decreasing	y = -13.912x + 565.26	-13.91	0.13
Dahanu	2.74	Decreasing	y = -2.0402x + 502.56	-2.04	0.00

The linear equation and rainfall trend in month of June was shown in Table 2 and Fig.2 for the tehsils of Palghar District. The non-significant (5 per cent level of significance) decreasing trend was observed at Vasai (-16.24 mm/year), Jawhar (-6.89 mm/year), Vikramgad (-5.60 mm/year), Wada (-9.62 mm/year), Talasari (-6.02 mm/year) and Mokhada (-13.91 mm/year) in month of June during 1998 – 2019. In Dahanu tehsil Kendall's tau and Sen's Slope value shows positive trend but regression slope values shows negative trend in month of June during 1998-2019. The result showed that non-significant (5 per cent level of significance) decreasing trend -2.04 mm/year for Dahanu tehsil in Palghar District during 1998-2019. The non-significant increasing trend 6.27 mm/year was observed at Palghar tehsil in month of June during 1998-2019.

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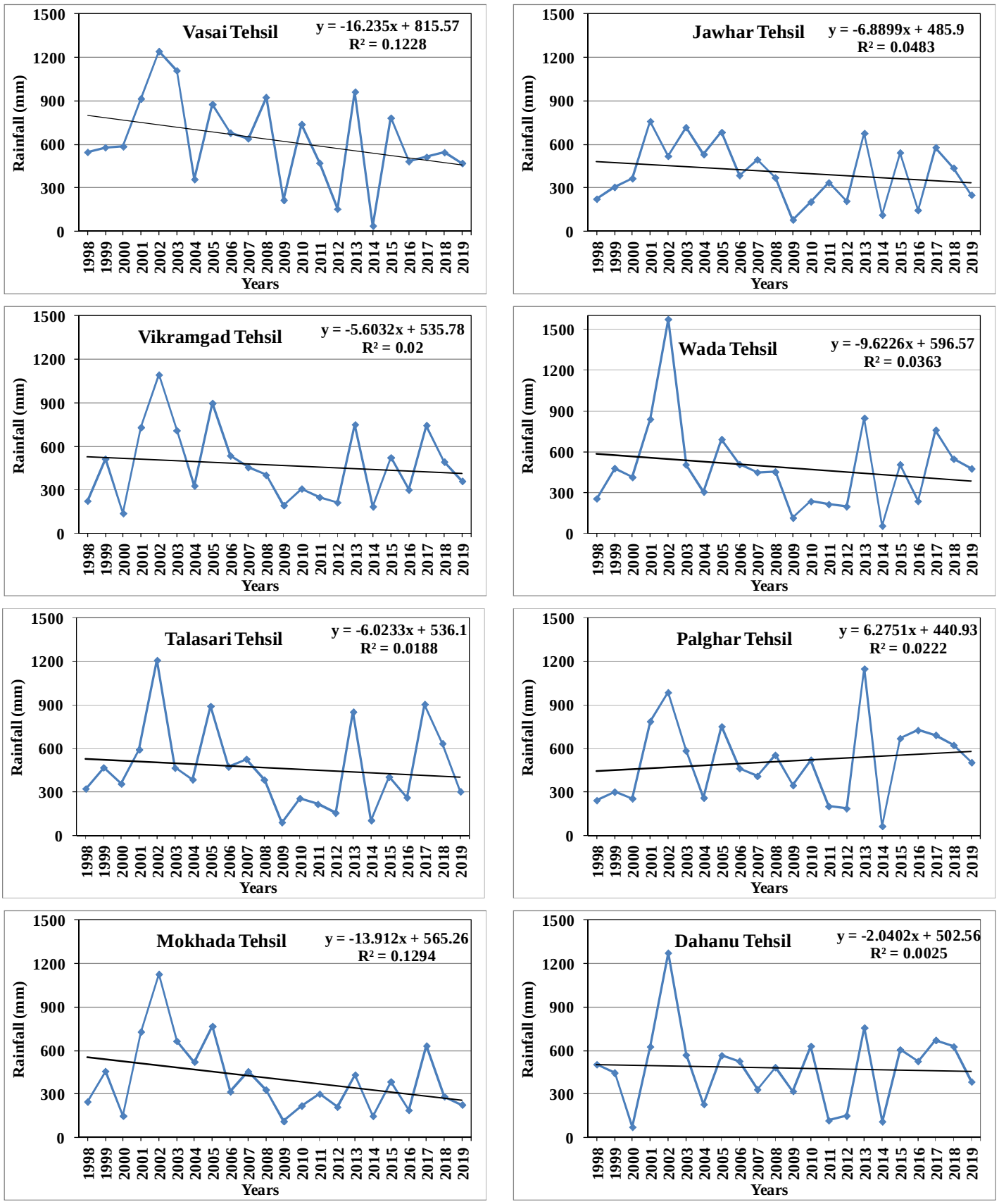


Figure 2 : Rainfall Trend analysis for month of June during 1998-2019 in tehsil of Palghar District

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B. Tehsil-wise Rainfall Trend Analysis for Month of July (1998-2019)

The mean rainfall in July month was given in Table 3 for the tehsils of Palghar District. The highest average rainfall 1147.1 mm was observed at Jawhar with 37.7 % variation and lowest at Dahanu tehsil 841.6 mm with a coefficient of variation 47.4 %.

Table 3: Statistical and Mann-Kendall trend analysis of rainfall for month of July during 1998-2019 in tehsils of Palghar district

Tehsils	Mean	SD	CV (%)	Kendall tau (Z)	S Statistics	P value	Significant
Vasai	1009.9	392.8	38.9	0.11	25.00	0.499	No
Jawhar	1147.1	432.2	37.7	0.48	111.00	0.002	Yes
Vikramgad	1071.9	341.8	31.9	0.45	103.00	0.004	Yes
Wada	998.5	320.9	32.1	0.40	93.00	0.009	Yes
Talasari	1014.3	394.7	38.9	0.42	97.00	0.007	Yes
Palghar	948.7	342.5	36.1	0.33	77.00	0.032	Yes
Mokhada	949.6	316.2	33.3	0.42	97.00	0.007	Yes
Dahanu	841.6	398.7	47.4	0.51	117.00	0.001	Yes

All tehsil receive more than 840 mm rainfall in month of July. The result showed that Jawhar tehsil was maximum deviation (432.2 mm) and a maximum variation was observed in Dahanu tehsil (47.4 %) in month of July during 1998-2019. The coefficient of variation month of July ranges from 31.9 % to 47.4 % in tehsil of Palghar district during 1998-2019. The Kendall's tau values of Vasai, Jawhar, Vikramgad, Wada, Talasari, Palghar, Mokhada and Dahanu were 0.11, 0.48, 0.45, 0.40, 0.42, 0.33, 0.42 and 0.51 with Sen's Slope Estimator (Q) 10.48, 43.80, 28.73, 29.64, 37.52, 25.48, 29.14 and 40.86 respectively.

Table 4: Sen's slope estimators and linear regression analysis for month of July during 1998-2019

Tehsil	Sen's Slope (Q)	Trend	Linear Equation	b (mm/year)	R^2
Vasai	10.48	Increasing	y = 2.7579x + 978.23	2.75	0.00
Jawhar	43.80	Increasing	y = 42.905x + 653.71	42.90	0.41
Vikramgad	28.73	Increasing	y = 29.9x + 728.09	29.9	0.32
Wada	29.64	Increasing	y = 24.056x + 721.89	24.05	0.02
Talasari	37.52	Increasing	y = 31.358 x + 653.69	31.35	0.26
Palghar	25.48	Increasing	y = 25.299x + 657.79	25.29	0.23
Mokhada	29.14	Increasing	y = 29.958x + 605.1	29.95	0.37
Dahanu	40.86	Increasing	y = 38.138x + 403.08	38.13	0.38

The linear equation and rainfall trend in month of July was shown in Table 4 and Fig.3 for the tehsils of Palghar District. The significant increasing trend was observed at Jawhar (42.91 mm/year), Vikramgad (29.90 mm/year), Wada (24.06 mm/year), Talasari (31.36 mm/year), Palghar (25.299 mm/year), Mokhada (29.96 mm/year) and Dahanu (38.14 mm/year) tehsil in month of July 1998-2019. The non-significant increasing trend 2.76 mm/year was observed at Vasai tehsil of Palghar District during 1998-2019.

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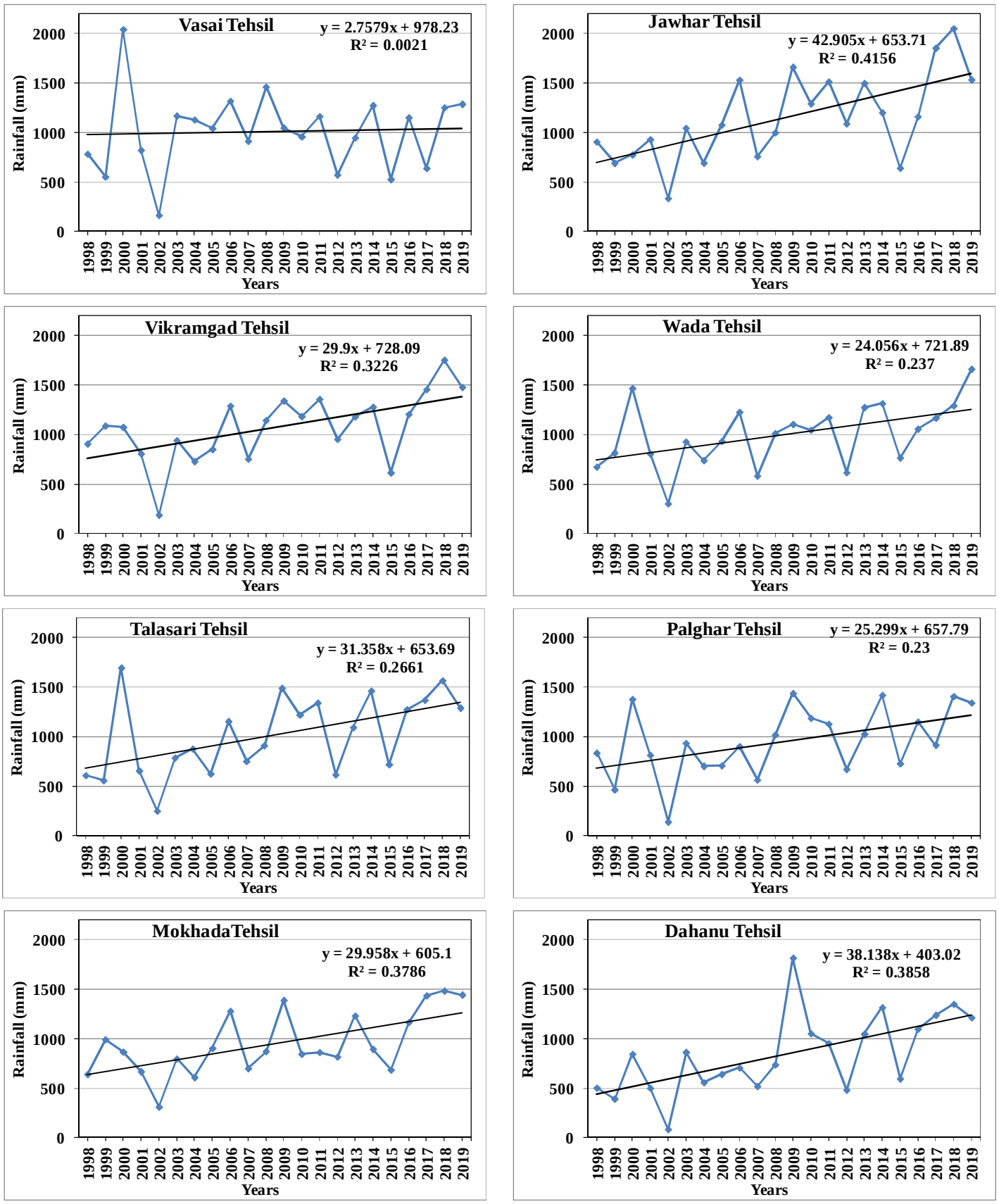


Figure 3 : Rainfall Trend analysis for month of July during 1998-2019 in tehsil of Palghar District

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C. Tehsil-wise Rainfall Trend Analysis for Month of August (1998-2019)

The highest average rainfall was observed at Jawhar tehsil (835.6 mm), followed by Vikramgad (756.7 mm), Mokhada (745.3 mm), Wada (720.3 mm), Talasari (695.0 mm), Vasai (660.8 mm), Palghar (610.3 mm) and Dahanu (560.1 mm) respectively.

Table 5: Statistical and Mann-Kendall trend analysis of rainfall for month of August during 1998-2019 in tehsils of Palghar district

Tehsils	Mean	SD	CV (%)	Kendall tau (Z)	S Statistics	P value	Significant
Vasai	660.8	352.1	53.3	-0.25	-57.00	0.114	No
Jawhar	835.6	439.7	52.6	0.09	21.00	0.573	No
Vikramgad	756.7	323.1	42.7	0.02	5.00	0.912	No
Wada	720.3	315.4	43.8	-0.02	-5.00	0.910	No
Talasari	695.0	297.0	42.7	0.06	13.00	0.735	No
Palghar	610.3	260.1	42.6	-0.08	-19.00	0.612	No
Mokhada	745.3	385.8	51.8	0.16	37.00	0.310	No
Dahanu	560.1	226.4	40.4	0.05	11.00	0.778	No

The result showed that Jawhar tehsil was observed maximum deviation (439.7 mm) with 52.6 % coefficient of variation for month of August. The coefficient of variation ranges from 40.4 % to 53.3 % in month of August for tehsil of Palghar district during 1998-2019.

The Kendall's tau values of Vasai, Jawhar, Vikramgad, Wada, Talasari, Palghar, Mokhada and Dahanu was -0.25, 0.09, 0.02, -0.02, 0.06, -0.08, 0.16 and 0.05 with Sen's Slope (Q) -18.95, 8.60, 1.10, -3.11, 4.42, -4.35, 7.33 and 1.78 respectively.

Table 6: Sen's slope estimators and linear regression analysis for month of August during 1998-2019

Tehsil	Sen's Slope (Q)	Trend	Linear Equation	b (mm/year)	R^2
Vasai	-18.95	Decreasing	y = -19.74x + 887.78	-19.74	0.13
Jawhar	8.60	Increasing	y = 5.0781x + 777.17	5.07	0.00
Vikramgad	1.10	Decreasing	y = -0.2962x + 760.06	-0.29	0.00
Wada	-3.11	Decreasing	y = -4.3422x + 770.24	-4.34	0.00
Talasari	4.42	Increasing	y = 1.4936 x + 677.84	1.49	0.00
Palghar	-4.35	Decreasing	y = -6.9188x + 689.91	-6.91	0.02
Mokhada	7.33	Increasing	y = 5.2128x + 685.39	5.21	0.00
Dahanu	1.78	Increasing	y = 0.4305x + 555.12	0.43	0.00

The linear equation and rainfall trend in month of August was shown in Table 6 and Fig. 4 for the tehsils of Palghar District. The non-significant increasing trend was observed at Jawhar (5.07 mm/year), Talasari (1.49 mm/year), Mokhada (5.21 mm/year) and Dahanu (0.43 mm/year) tehsil in month of August during 1998-2019.

The non-significant decreasing trend was observed at Vasai (-19.74 mm/year), Wada (-4.34 mm/year) and Palghar (-6.91 mm/year) in tehsil of Palghar District during 1998-2019. The regression analysis showed that non-significant (5 per cent level of significance) decreasing trend -0.29 mm/year for Vikramgad tehsil in Palghar District during 1998-2019.

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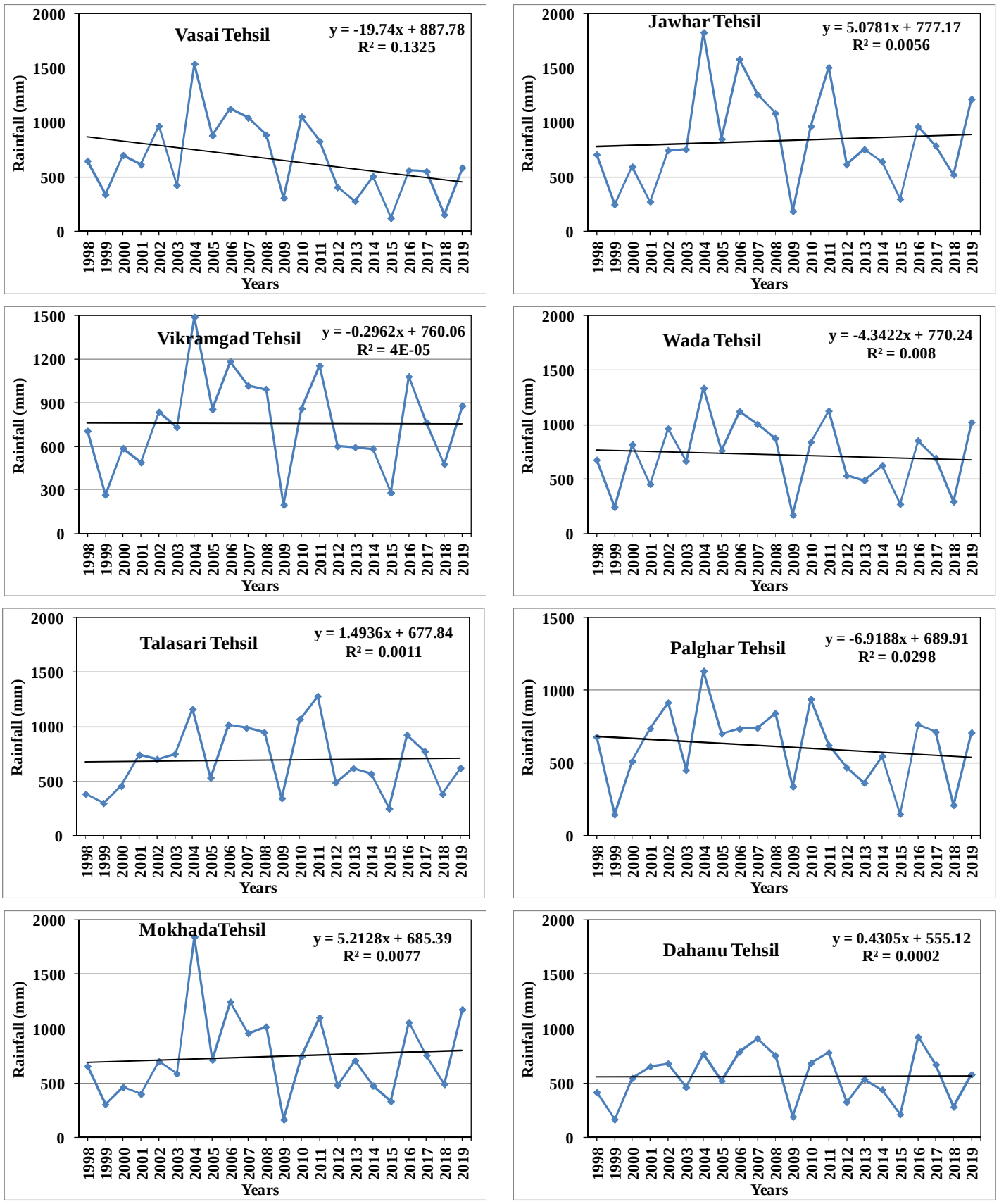


Figure 4 : Rainfall Trend analysis for month of August during 1998-2019 in tehsil of Palghar District

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D. Tehsil-wise Rainfall Trend Analysis for Month of September (1998-2019)

The highest average rainfall was observed at Vasai tehsil 428.1 mm with 72.1 % variation and lowest rainfall at Mokhada tehsil 331.2 mm with a coefficient of variation 62.5 %. All tehsil receive more than 300 mm rainfall in month of September. The maximum standard deviation was observed in Palghar (350.8 mm) followed by Vasai (308.6 mm), Dahanu (284.1 mm), Jawhar (273.4 mm), Talasari (260.4 mm), Wada (234.6 mm), Vikramgad (233.8 mm) and Mokhada (207.0 mm) with coefficient of variation 86.4 %, 72.1 %, 77.3 %, 74.9 %, 68.9 %, 61.9 %, 67.4 % and 62.5 %, respectively in tehsil of Palghar district during 1998-2019.

Table 7: Statistical and Mann-Kendall trend analysis of rainfall for month of September during 1998-2019 in tehsils of Palghar district

Tehsils	Mean	SD	CV (%)	Kendall tau (Z)	S Statistics	P value	Significant
Vasai	428.1	308.6	72.1	0.02	5.00	0.910	No
Jawhar	365.1	273.4	74.9	0.09	21.00	0.573	No
Vikramgad	347.0	233.8	67.4	0.14	33.00	0.367	No
Wada	378.9	234.6	61.9	0.01	3.00	0.955	No
Talasari	377.8	260.4	68.9	0.17	39.00	0.284	No
Palghar	406.0	350.8	86.4	0.07	17.00	0.652	No
Mokhada	331.2	207.0	62.5	0.07	17.00	0.652	No
Dahanu	367.6	284.1	77.3	0.30	69.00	0.055	No

The Table 7 shows Kendall's tau values of Vasai, Jawhar, Vikramgad, Wada, Talasari, Palghar, Mokhada and Dahanu was 0.02, 0.09, 0.14, 0.01, 0.17, 0.07, 0.07 and 0.30 with Sen's Slope Estimator (Q) 1.67, 5.90, 6.56, 1.09, 10.79, 2.66, 3.43 and 14.26 respectively.

Table 8: Sen's slope estimators and linear regression analysis for month of September during 1998 2019

Tehsil	Sen's Slope (Q)	Trend	Linear Equation	b (mm/year)	R^2
Vasai	1.67	Decreasing	y = -2.3734x + 455.44	-2.37	0.00
Jawhar	5.90	Increasing	y = 1.2432x + 350.84	1.24	0.00
Vikramgad	6.56	Increasing	y = 3.2567x + 309.53	3.25	0.00
Wada	1.09	Decreasing	y = -1.4718x + 395.84	-1.47	0.00
Talasari	10.79	Increasing	y = 4.1872 x + 329.62	4.18	0.01
Palghar	2.66	Increasing	y = 0.5056 x + 400.23	0.50	0.00
Mokhada	3.43	Increasing	y = 1.9149x + 309.14	1.91	0.00
Dahanu	14.26	Increasing	y = 16.839x + 173.97	16.83	0.14

The linear equation and rainfall trend in month of September was shown in Table 8 and Fig. 5 for the tehsils of Palghar District. The regression analysis showed non-significant increasing trend at Jawhar (1.24 mm/year), Vikramgad (3.25 mm/year), Talasari (4.18 mm/year), Palghar (0.50 mm/year), Mokhada (1.91 mm/year) and Dahanu (16.83 mm/year) tehsil in month of September during 1998-2019.

The regression analysis showed non-significant decreasing trend at Vasai (-2.37 mm/year) and Wada (-1.47 mm/year).

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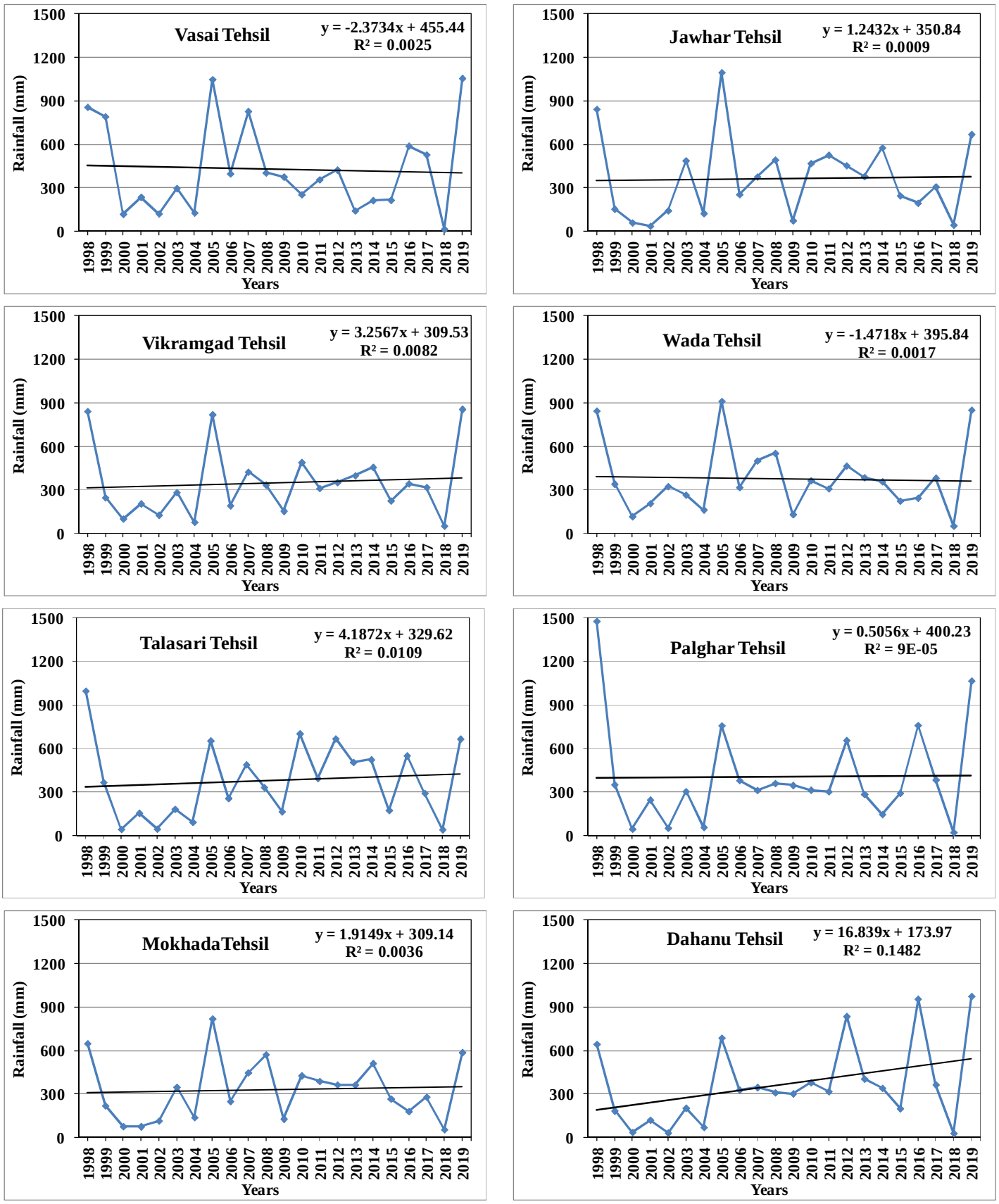


Figure 5 : Rainfall Trend analysis for month of September during 1998-2019 in tehsil of Palghar District

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E. Tehsil-wise Rainfall Trend Analysis for Month of October (1998-2019)

The highest average rainfall 96.1 mm was observed at Mokhada with 85.2 % variation and lowest rainfall observed at Dahanu tehsil 47.7 mm with a coefficient of variation 122.2 %. All tehsil receive less than 90 mm average rainfall in month of October. The coefficient of variation was month of July ranges from 69.5 % to 122.2 % in tehsil of Palghar district during 1998-2019.

Table 9: Statistical and Mann-Kendall trend analysis of rainfall for month of October during 1998-2019 in tehsils of Palghar district

Tehsils	Mean	SD	CV (%)	Kendall tau (Z)	S Statistics	P value	Significant
Vasai	86.4	98.5	114.0	-0.19	-43.00	0.235	No
Jawhar	68.1	56.2	82.5	0.04	10.00	0.800	No
Vikramgad	73.8	51.3	69.5	0.02	5.00	0.910	No
Wada	73.7	65.2	88.5	-0.01	-2.00	0.977	No
Talasari	54.4	58.7	107.9	-0.04	-9.00	0.821	No
Palghar	65.3	71.2	109.0	-0.01	-2.00	0.977	No
Mokhada	96.1	81.9	85.2	-0.15	-34.00	0.352	No
Dahanu	47.7	58.2	122.2	0.09	20.00	0.592	No

The Table 9 shows Kendall's tau values of Vasai, Jawhar, Vikramgad, Wada, Talasari, Palghar, Mokhada and Dahanu was -0.19, 0.04, 0.02, -0.01, -0.04, -0.01, -0.15 and 0.09 with Sen's Slope Estimator (Q) -2.77, 0.59, 0.22, -0.33, -0.17, -0.02, -1.63 and 0.86 respectively. The non-significant (5 per cent level of significance) increasing trend was observed in Jawhar, Vikramgad and Dahanu tehsil of Palghar District during 1998 to 2019. The non-significant (5 per cent level of significance) decreasing trend was observed in Vasai, Wada, Talasari, Palghar and Mokhada tehsil of Palghar District during 1998 to 2019.

Table 10: Sen's slope estimators and linear regression analysis for month of October during 1998-2019

Tehsil	Sen's Slope (Q)	Trend	Linear Equation	b (mm/year)	R^2
Vasai	-2.77	Decreasing	y = -6.3612x + 159.53	-6.36	0.17
Jawhar	0.59	Increasing	y = 0.751 x + 59.413	0.75	0.00
Vikramgad	0.22	Increasing	y = 0.14x + 72.199	0.14	0.00
Wada	-0.33	Decreasing	y = -1.1719x + 87.14	-1.17	0.01
Talasari	-0.17	Decreasing	y = -1.0326 x + 66.257	-1.03	0.01
Palghar	-0.02	Decreasing	y = -1.4333 x + 81.76	-1.43	0.01
Mokhada	-1.63	Decreasing	y = -4.0355x + 142.5	-4.03	0.10
Dahanu	0.86	Increasing	y = -1.0399 x + 59.618	16.83	0.01

The linear equation and rainfall trend in month of October was shown in Table 10 and Fig.6 for the tehsils of Palghar District. The non-significant increasing trend was observed at Jawhar (0.75 mm/year) and Vikramgad (0.14 mm/year) in month of August. The non-significant decreasing trend was observed at Vasai (-6.36 mm/year), Wada (-1.17 mm/year), Talasari (-1.03 mm/year), Palghar (-1.43 mm/year) and Mokhada (-4.03 mm/year) tehsil of Palghar District during 1998-2019. The regression analysis showed non-significant decreasing trend at Vasai (-6.36 mm/year) and Wada (-1.17 mm/year) and Dahanu (-1.03 mm/year) during 1998-2019.

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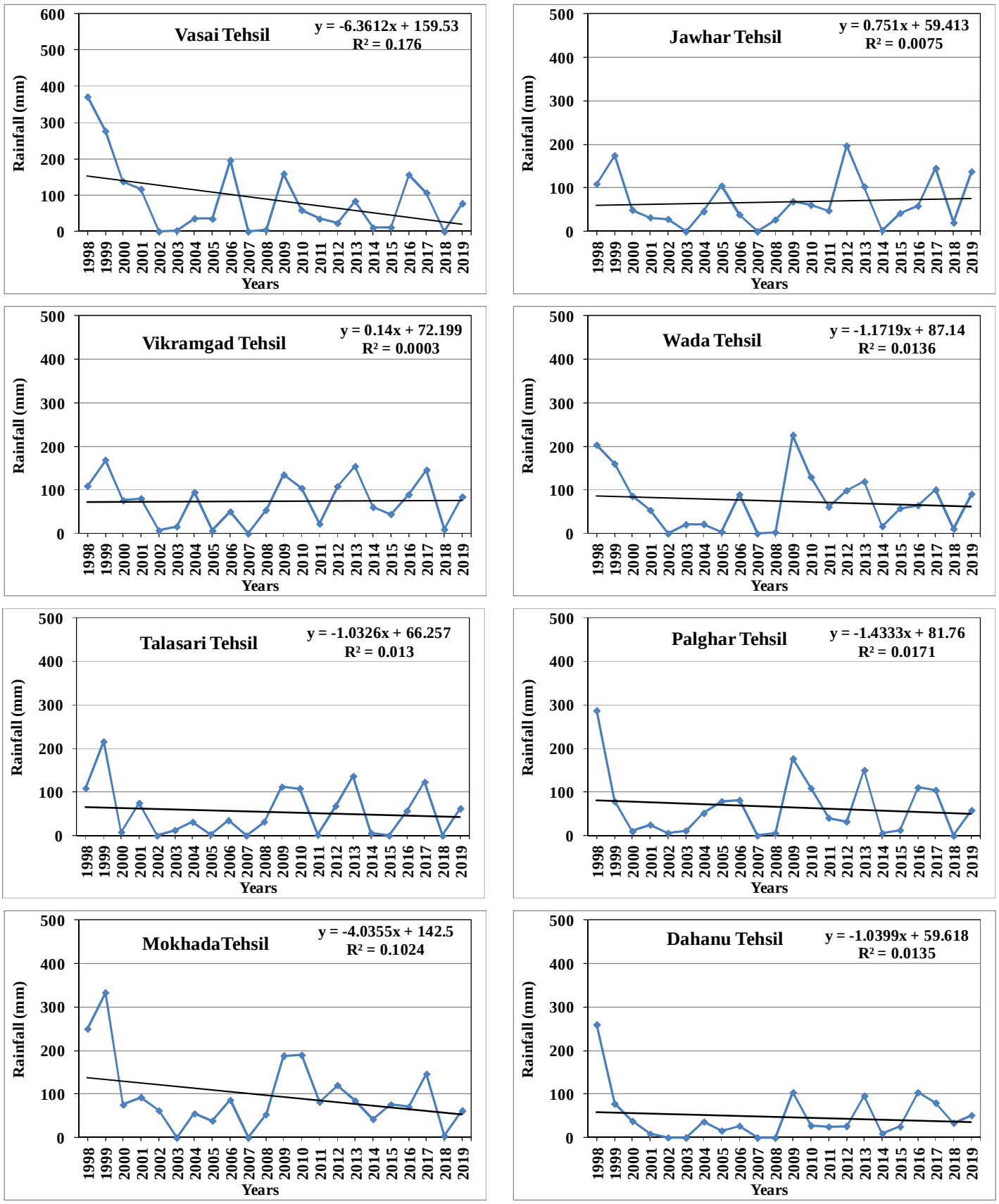


Figure 6 : Rainfall Trend analysis for month of October during 1998-2019 in tehsil of Palghar District

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F. Annual Rainfall Trend Analysis

Table 11: Statistical and Mann-Kendall trend analysis of annual rainfall during 1998-2019 in tehsils of Palghar district

Tehsils	Mean	SD	CV (%)	Kendall tau (Z)	S Statistics	P value	Significant
Vasai	2855.9	713.3	25.0	-0.30	-69.00	0.06	No
Jawhar	2839.1	736.5	25.9	0.26	61.00	0.09	No
Vikramgad	2738.9	514.3	18.8	0.25	57.00	0.11	No
Wada	2674.0	568.5	21.3	-0.004	-1.0	1.0	No
Talasari	2633.3	502.5	19.1	0.32	73.00	0.042	Yes
Palghar	2570.8	597.2	23.2	0.126	29.00	0.430	No
Mokhada	2543.6	514.6	20.2	0.18	41.00	0.26	No
Dahanu	2318.5	571.2	24.6	0.44	101.00	0.005	Yes

The average annual rainfall in Vasai tehsil during 1998 to 2019 was maximum (2855.9 mm), followed by Jawhar (2839.1 mm), Vikramgad (2738.9 mm), Wada (2674.0 mm), Talasari (2633.3 mm), Palghar (2570.8 mm), Mokhada (2543.6 mm) and Dahanu (2318.5 mm) with coefficient of variation 25.0 %, 25.9 %, 18.8 %, 21.3 %, 19.1 %, 23.2 %, 20.2 % and 24.6 % respectively.

Table 12: Sen's slope estimators and linear regression analysis of annual rainfall during 1998-2019

Tehsil	Sen's Slope (Q)	Trend	Linear Equation	b (mm/year)	R^2
Vasai	-42.19	Decreasing	y = -44.614x + 3369	-44.61	0.16
Jawhar	49.27	Increasing	y = 43.589x + 2337.9	43.59	0.15
Vikramgad	37.96	Increasing	y = 27.442x + 2423.4	27.44	0.12
Wada	-1.19	Increasing	y = 6.9899x + 2593.6	6.99	0.01
Talasari	36.09	Increasing	y = 29.827x + 2290.3	29.83	0.15
Palghar	22.9	Increasing	y = 23.263x + 2303.3	23.26	0.06
Mokhada	20.70	Increasing	y = 18.416x + 2331.8	18.42	0.05
Dahanu	58.70	Increasing	y = 52.754x + 1711.9	52.75	0.36

The Kendall's tau values of Vasai, Jawhar, Vikramgad, Wada, Talasari, Palghar, Mokhada and Dahanu tehsil was -0.30, 0.26, 0.25, 0.00, 0.32, 0.126, 0.18 and 0.44 with Sen's Slope Estimator (Q) -42.19, 49.27, 37.96, -1.2, 36.09, 22.9, 20.70 and 58.70 respectively. A positive or negative value of Kendall tau (Z) indicates an upward or downward trend.

The table 12 showed that non-significant (5 per cent level of significance) increasing annual rainfall trend was observed at Jawhar (43.59 mm/year), Vikramgad (27.44 mm/year), Wada (6.99 mm/year), Palghar (23.26 mm/year) and Mokhada (23.26 mm/year) in tehsil of Palghar District during 1998 – 2019. In Table 7 showed that significant (5 per cent level of significance) increasing rainfall trend was observed at Talasari (29.83 mm/year) and Dahanu (23.26 mm/year) in tehsil of Palghar District during 1998 – 2019. The result showed that annual rainfall trend was decreased by -44.61 mm/year for Vasai tehsil in Palghar District during 1998-2019.

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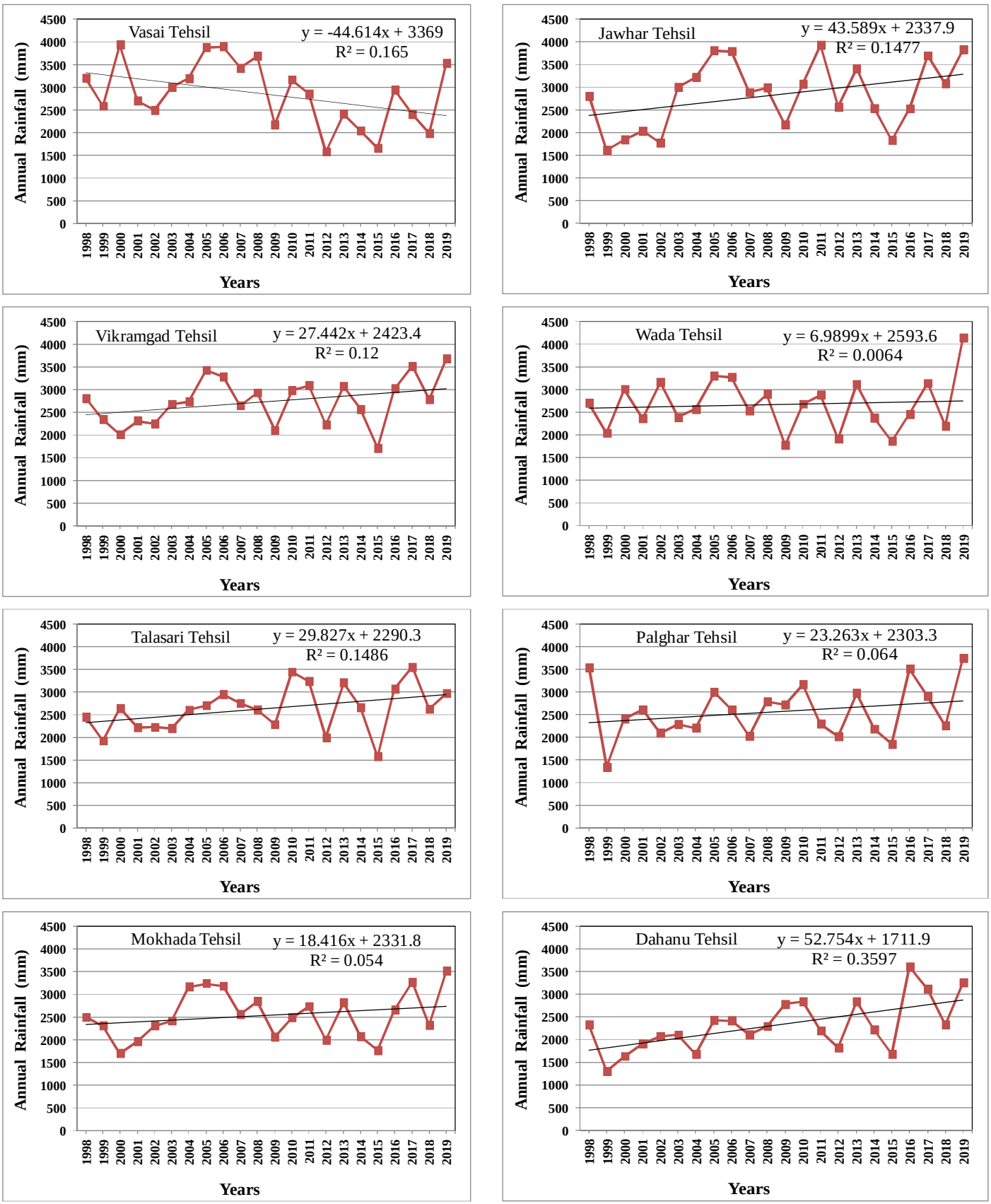


Figure 7 : Annual Rainfall Trend analysis during 1998-2019 in tehsil of Palghar District

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IV. CONCLUSION

The daily rainfall data of 22 years (1998 to 2019) was used to access the monthly and annual trend of rainfall. The average annual rainfall in Vasai tehsil during 1998 to 2019 was maximum (2855.9 mm), followed by Jawhar (2839.1 mm), Vikramgad (2738.9 mm), Wada (2674.0 mm), Talasari (2633.3 mm), Palghar (2570.8 mm), Mokhada (2543.6 mm) and Dahanu (2318.5 mm) with coefficient of variation 25.0 %, 25.9 %, 18.8 %, 21.3 %, 19.1 %, 23.2 %, 20.2 % and 24.6 % respectively. The month of July significant increasing trend was observed at Jawhar (42.91 mm/year), Vikramgad (29.90 mm/year), Wada (24.06 mm/year), Talasari (31.36 mm/year), Palghar (25.299 mm/year), Mokhada (29.96 mm/year) and Dahanu (38.14 mm/year), whereas non-significant increasing trend 2.76 mm/year was observed at Vasai tehsil of Palghar District during 1998-2019. The month of June, August, September and October rainfall did not show any significant trend in tehsil of Palghar District and non significant decreasing as well as non significant increasing trend was observed in tehsil of Palghar District during 1998 – 2019.

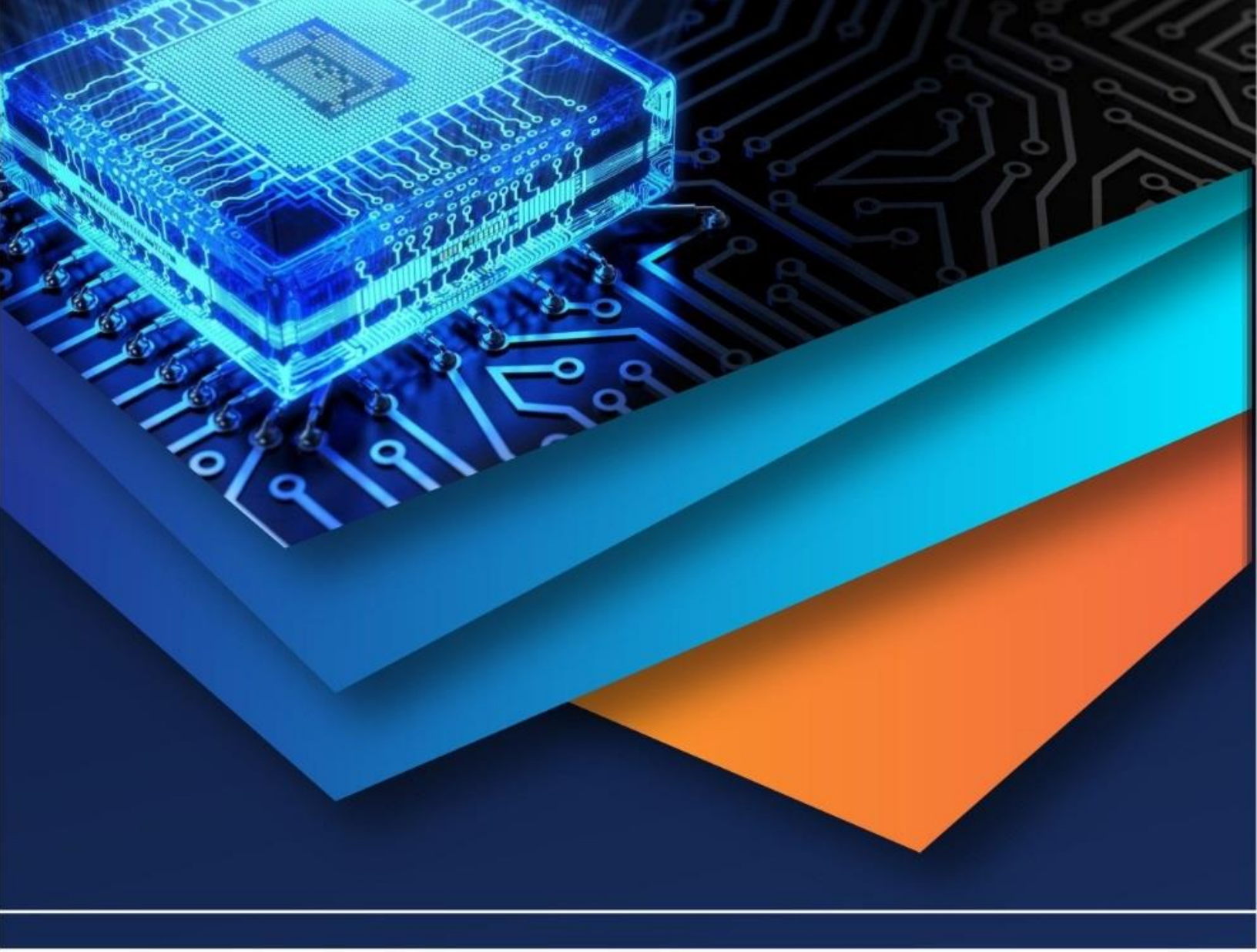
The result found that significant (5 per cent level of significance) increasing annual rainfall trend was observed at Talasari (29.83 mm/year) and Dahanu (23.26 mm/year) in tehsil of Palghar District during 1998 – 2019. The non significant increasing annual rainfall trend was observed in Jawhar (43.59 mm/year), Vikramgad (27.44 mm/year), Wada (6.99 mm/year), Palghar (23.26 mm/year) and Mokhada (23.26 mm/year) in tehsil of Palghar District during 1998 – 2019. The non significant decreasing annual rainfall trend was observed in Vasai tehsil (-44.61 mm/year) in Palghar District during 1998-2019. As per result it is concluded that annual rainfall trend was increased in tehsils namely Jawhar, Vikramgad, Wada, Talasari, Palghar, Mokhada and Dahanu; whereas in Vasai tehsil rainfall trend was decreased during 1998 -2019.

The results obtained in this work are promising and might help engineers when designing the water resources structures and decision makers of agricultural sector in the tehsil of Palghar District. Trend analysis of rainfall might help micro level for the better water and crop planning for the tehsil of Palghar District. The study findings help farmers in better understanding of the inevitable climate change with respect to rainfall to adopt themselves by taking suitable measures and strategies to combat the change. It is recommended that government policies in this area should be based on recent rainfall trends.

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