iJRASET
International Journal For Research in Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 9 **Issue:** VII **Month of publication:** July 2021

DOI: https://doi.org/10.22214/ijraset.2021.36931

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue VII July 2021- Available at www.ijraset.com

Statistical Analysis of Rainfall Variability for Tehsils of Palghar District, Maharashtra State, India

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Abstract: ***A detailed statistical analysis of monthly, seasonal 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. The mean, standard deviation and coefficient of variation for monthly, seasonal and annual rainfall were computed for tehsils of Palghar districts. The month of July received maximum monthly mean rainfall for all years (1998 to 2019) in tehsils of Palghar district. The result showed that monthly mean rainfall in month of July was maximum at Jawhar (1147.1 mm) followed by Vikramgad (1071.9 mm), Talasari (1014.3 mm), Vasai (1009.9 mm), Wada (998.5 mm), Mokhada (949.6 mm), Palghar (948.7 mm) and Dahanu (841.6) with contributes 40.4 %, 39.1 %, 38.5 %, 35.4 %, 37.3 %, 37.3 %, 36.9 % and 36.3 % of the annual mean rainfall (1998 to 2019) respectively. The result showed that contribution of rainfall during Monsoon season ranges from 95.5 % to 97.0 % of the annual total rainfall for tehsils of Palghar District. The result showed that average annual rainfall (1998 to 2019) of Vasai, Jawhar, Vikramgad, Wada, Talasari, Palghar, Mokhada and Dahanu were 2855.9 mm, 2839.1 mm, 2738.9 mm, 2674.0 mm, 2633.3 mm, 2570.8 mm, 2543.6 mm and 2318.5 mm respectively.***

Keywords: Rainfall, Coefficient of Variation, Rainfall Variability, Monsoon Season

I. INTRODUCTION

Water is one of our most valuable natural resources and vital to all forms of life. Water is also used for transportation, is source of power, and serves many other useful purposes for domestic consumption, agriculture, and industry. The main important source of water in any area is rain.

The amount or availability of water for various purposes is very much depending upon the amount of precipitation in that particular area. Excess or extended absence of rainfall will cause flooding and drought, respectively. Adler et al., (2000) stated that precipitation information is essential for understanding the hydrologic balance on a global scale and for understanding the complex interactions among the components within the hydrologic cycle.

Rainfall is one of the most important natural resource input to crop production in the tropical region. Out of 189.54 million ha (1996-97) gross cropped area (including area sown more than once) of the country, 61.3% (116.26 million ha) falls under rainfed farming. In India, the gross irrigated area has been rapidly increasing from 28 million ha in 1960-61 to 72.8 million ha in 1997-98 (DES, 2001).

Despite this progress, marginal and small farmers constituting 80% of agricultural income group, still depend on rainfed farming. The early or delay in onset of monsoon, early or late withdrawal of monsoon, breaks in monsoon period, unusual heavy or no rainfall during the critical phenol-phase of crops may disturb the normal crop growth and development. To exploit the available rainfall effectively, crop planning and management practices must be followed based on the rainfall amount and distribution at a place (Bhakar et al., 2008).

Rainfall is the meteorological phenomenon that has the greatest impact on human activities and the most important environmental factor limiting the development of the semiarid regions (Kipkorir, 2002). 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). Krishnakumar (2008) studied temporal variation in monthly, seasonal and annual rainfall over Kerala, India and revealed the significant decrease in southwest monsoon rainfall while increase in post monsoon season.

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Krishnamurty and Shukla (2005) studied the inter-seasonal and seasonally persisting patterns of Indian monsoon rainfall. While the other fellow such as Gill et al., *(*2010) processed on the variability in climate temperature and rainfall in these different agro climatic regions of Punjab. Upadhaya (2014) made an attempt to study the variability of rainfall in Rajasthan, India for the period of 50 years (1960-2009).

The result showed that contribution of winter, summer and Post- Monsoon season's rainfall amounts to about 2%, 3% and 4% respectively of the annual total rainfall.

No such a work was reported for tehsils of Palghar districts; therefore present research study was undertaken to know about rainfall variability of tehsils of Palghar districts. To know about rainfall variability for tehsils of Palghar districts is very essential and important for future planning.

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.

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, seasonal and annual rainfall. These 22 years data was future used for the rainfall variability analysis and time series analysis such as mean rainfall, standard deviation and coefficient of variation.

D. *Mean Rainfall*

The amount of rainfall collected by a given rain gauge in 24 hrs is known as daily rainfall (mm or cm) and the amount collected in one year in known as annual rainfall. The mean of the annual rainfall over of 35 years (in India) is known as mean annual rainfall (average annual rainfall or normal annual rainfall).

$$\text{Mean Rainfall} = \frac{\text{Total Rainfall}}{\text{Number of Years}} \quad \ldots(1)$$

E. *Standard Deviation (SD)*

It is defined as the square root of the mean of the squares of deviations of the rainfall value from the arithmetic mean of all such rainfall. It is a measure of variability or the scatter or the dispersion about the mean value. It is given by the following formula.

$$\text{Standard Deviation (SD)} = \sqrt{\frac{\sum(X-\bar{X})^2}{n-1}} \quad \ldots(2)$$

X = Rainfall

$\bar{X}$= Mean rainfall

n = Number of year

F. *Coefficient of Variation*

Assessment of rainfall variability through Coefficient of variation (CV %) appears to be simple. CV is defined as the Standard deviation divided by the mean value of rainfall. It shows the variability of rainfall in percentage.

$$\text{Coefficient of variation (CV)} = \frac{\text{Standard Deviation}}{\text{Mean}} \times 100 \quad \ldots(3)$$

The greater the coefficient of variation, lesser the dependability of receiving rainfall. The coefficient of variation indicates the amount of fluctuation in rainfall recorded over a long period of time from the mean values. The coefficient of variation of variation of annual rainfall is an index of climatic risk.

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III. RESULTS AND DISCUSSION

The tehsil-wise monthly, seasonal (June to September) and annual rainfall was analysed. The results obtained are discuses below:

A. Tehsil-wise Monthly Rainfall Analysis

1) Monthly Rainfall Analysis of Vasai Tehsil: Table 1 showed that monthly rainfall analysis of Vasai Tehsil during 1998-2019 over a 22 year period. The result showed that highest rainfall occurred in the month of July in 13 years out of the 22 years, followed by the month of June (4 years), August (3 years) and September (2 years).

Table 1: Monthly variation of mean rainfall (mm) of Vasai tehsil during 1998-2019

Year	Jan.	Feb.	March	April	May	June	July	August	Sept.	Octo.	Nov.	Dec.	Annual Rainfall
1998	0.0	0.0	0.0	0.0	0.0	547.0	783.0	648.0	857.0	371.0	2.0	0.0	3208.0
1999	0.0	0.0	0.0	0.0	49.0	579.5	553.0	341.0	792.0	277.0	0.0	0.0	2591.5
2000	0.0	0.0	0.0	0.0	346.0	586.0	2041.0	700.1	121.0	138.0	0.0	7.0	3939.1
2001	0.0	0.0	0.0	0.0	0.0	915.0	822.0	615.4	237.3	117.0	0.0	0.0	2706.7
2002	0.0	0.0	0.0	0.0	0.0	1241.0	165.0	968.0	123.0	0.0	0.0	0.0	2497.0
2003	0.0	0.0	0.0	0.0	0.0	1108.0	1169.0	425.0	298.0	3.0	0.0	0.0	3003.0
2004	0.0	0.0	0.0	0.0	0.0	360.0	1130.0	1540.0	129.0	36.0	0.0	0.0	3195.0
2005	0.0	0.0	0.0	0.0	0.0	876.0	1042.8	882.0	1048.0	35.0	0.0	0.0	3883.8
2006	0.0	0.0	37.0	0.0	145.0	679.0	1318.0	1126.0	398.7	196.0	0.0	0.0	3899.7
2007	0.0	0.0	0.0	0.0	0.0	640.0	912.6	1043.0	828.0	0.0	0.0	0.0	3423.6
2008	0.0	0.0	0.0	0.0	8.0	924.0	1461.0	887.0	405.0	5.0	0.0	0.0	3690.0
2009	0.0	0.0	0.0	0.0	0.0	217.0	1047.0	309.0	377.0	159.0	72.0	0.0	2181.0
2010	0.0	0.0	0.0	0.0	0.0	738.0	958.0	1053.0	255.0	59.0	107.0	0.0	3170.0
2011	0.0	0.0	0.0	0.0	0.0	472.0	1163.6	829.0	358.0	35.0	0.0	0.0	2857.6
2012	0.0	0.0	0.0	0.0	0.0	156.0	573.0	407.0	425.0	23.0	0.0	0.0	1584.0
2013	0.0	0.0	0.0	0.0	0.0	962.8	947.7	279.2	144.0	83.8	0.0	0.0	2417.5
2014	0.0	0.0	0.0	0.0	0.0	39.0	1274.1	506.5	214.5	10.2	0.0	0.0	2044.3
2015	0.0	0.0	0.0	0.0	0.0	782.9	527.7	124.0	217.2	11.6	0.7	0.0	1664.1
2016	0.0	0.0	0.0	0.0	0.0	483.3	1151.1	561.4	589.8	156.6	0.0	0.0	2942.2
2017	0.0	0.0	0.0	0.0	0.0	513.2	638.8	552.4	529.6	107.0	0.0	66.5	2407.5
2018	0.0	0.0	0.0	0.0	21.3	544.8	1252.7	153.8	16.8	0.0	0.0	0.0	1989.4
2019	0.0	0.0	0.0	0.0	0.0	470.7	1287.7	586.0	1055.2	77.1	58.4	0.7	3535.8
Mean	0.0	0.0	1.7	0.0	25.9	628.9	1009.9	660.8	428.1	86.4	10.9	3.4	2855.9
SD	0.0	0.0	7.9	0.0	78.4	300.8	392.8	352.1	308.6	98.5	28.8	14.2	713.3
CV (%)	-	-	469.0	-	302.8	47.8	38.9	53.3	72.1	114.0	264.0	420.4	25.0

During this 22 year period, the highest mean rainfall of 1009.9 mm occurred in the month of July, followed by August (660.8 mm), June (628.9 mm), September (428.1 mm) while the months of October, May, November, December and March experienced relatively low rainfall (86.4 mm, 25.9 mm, 10.9 mm, 3.4 mm and 1.6 mm, respectively). There was no rain in the months of January, February and April during period of 1998–2019. The monthly coefficient of variation value varies from 38.9 % to 469.0 %. The results showed that coefficient of variation of monsoon months (June to September) were lower than other months.

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2) *Monthly Rainfall analysis of Jawhar Tehsil:* Table 2 showed that monthly rainfall analysis of Jawhar tehsil during 1998-2019 over a 22 year period. The result showed that highest rainfall occurred in the month of July in 16 years out of the 22 years, followed by the month of August (5 years) and September (1 year).

Table 2: Monthly variation of mean rainfall (mm) of Jawhar tehsil during 1998-2019

Year	Jan.	Feb.	March	April	May	June	July	August	Sept.	Octo.	Nov.	Dec.	Annual Rainfall
1998	0.0	0.0	0.0	0.0	0.0	224.6	906.8	706.6	842.8	109.4	14.0	0.0	2804.2
1999	0.0	0.0	0.0	0.0	42.0	306.0	691.6	248.9	155.4	174.4	0.0	0.0	1618.3
2000	0.0	0.0	0.0	0.0	2.0	365.8	774.7	595.0	61.1	49.6	0.0	0.0	1848.2
2001	0.0	0.0	0.0	0.0	0.0	759.2	930.4	274.4	38.4	32.2	2.6	0.0	2037.2
2002	0.0	0.0	0.0	0.0	0.0	519.6	335.8	745.2	144.3	28.4	0.0	0.0	1773.3
2003	0.0	0.0	0.0	0.0	0.0	717.1	1045.3	753.2	488.6	0.0	0.0	0.0	3004.2
2004	0.0	0.0	0.0	0.0	0.0	532.1	692.6	1826.6	125.8	46.6	0.0	0.0	3223.7
2005	0.0	0.0	0.0	0.0	0.0	684.0	1076.5	849.8	1095.4	105.2	0.0	0.0	3810.9
2006	0.0	0.0	0.0	0.0	0.0	387.0	1530.6	1582.1	256.0	38.8	0.0	0.0	3794.5
2007	0.0	0.0	0.0	0.0	0.0	495.1	758.1	1258.0	377.6	0.0	0.0	0.0	2888.8
2008	0.0	0.0	0.0	0.0	16.0	371.3	999.0	1086.0	494.0	27.0	0.0	0.0	2993.3
2009	0.0	0.0	0.0	0.0	0.0	81.0	1662.0	187.0	76.0	69.0	97.0	0.0	2172.0
2010	0.0	0.0	0.0	0.0	0.0	205.0	1292.0	966.0	470.0	61.0	81.0	0.0	3075.0
2011	0.0	0.0	0.0	0.0	0.0	337.0	1513.2	1507.0	527.0	48.0	0.0	0.0	3932.2
2012	0.0	0.0	0.0	0.0	0.0	210.0	1088.0	616.0	455.0	197.0	0.9	0.0	2566.9
2013	0.0	0.0	0.0	0.0	0.0	677.0	1498.6	752.8	380.0	103.0	0.0	0.0	3411.4
2014	0.0	0.0	0.0	0.0	0.0	114.5	1201.5	641.0	578.0	3.0	0.0	0.0	2538.0
2015	0.0	0.0	0.0	0.0	0.0	543.3	641.0	298.5	247.0	42.0	59.5	0.0	1831.3
2016	0.0	0.0	0.0	0.0	0.0	147.0	1161.3	963.5	196.6	59.0	0.0	0.0	2527.4
2017	0.0	0.0	0.0	0.0	0.0	579.6	1853.9	787.2	308.5	145.3	0.0	22.0	3696.5
2018	0.0	0.0	4.4	0.0	0.6	438.2	2050.5	522.0	45.5	20.5	0.0	0.0	3081.7
2019	0.0	0.0	0.0	0.0	0.0	252.2	1533.4	1215.8	670.1	137.7	22.4	0.4	3832.0
Mean	0.0	0.0	0.2	0.0	2.8	406.7	1147.1	835.6	365.1	68.1	12.6	1.0	2839.1
SD	0.0	0.0	0.9	0.0	9.4	203.5	432.2	439.7	273.4	56.2	28.2	4.7	736.5
CV (%)	-	-	469.0	-	341.4	50.1	37.7	52.6	74.9	82.5	223.8	460.3	25.9

During this 22 year period, the highest mean rainfall of 1147.1 mm occurred in the month of July, followed by August (835.6 mm), June (406.7 mm), September (365.1 mm) while the months of October, November, May, December and March experienced relatively low rainfall (68.1 mm, 12.6 mm, 2.8 mm, 1.0 mm and 0.2 mm, respectively). There was no rain in the months of January, February and April during period of 1998-2019 in Jawhar tehsil. The monthly coefficient of variation value varies from 37.7 % to 469.0 %. It showed that coefficient of variation of monsoon months (June to September) were lower than other months.

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3) *Monthly Rainfall Analysis of Vikramgad Tehsil:* Table 3 showed that monthly rainfall analysis of Vikramgad tehsil during 1998-2019 over a 22 year period. The result showed that highest rainfall occurred in the month of July in 14 years out of the 22 years, followed by the month of August (4 years), June (2 years) and September (2 years).

Table 3: Monthly variation of mean rainfall (mm) of Vikramgad tehsil during 1998-2019

Year	Jan.	Feb.	March	April	May	June	July	August	Sept.	Octo.	Nov.	Dec.	Annual Rainfall
1998	0.0	0.0	0.0	0.0	0.0	224.8	906.8	706.6	842.8	109.4	14.0	0.0	2804.4
1999	0.0	0.0	0.0	0.0	60.4	514.3	1088.3	266.3	248.3	169.0	0.0	0.0	2346.6
2000	0.0	0.0	0.0	0.0	34.6	139.9	1074.8	587.4	102.2	75.9	0.0	0.0	2014.8
2001	0.0	0.0	0.0	0.0	0.0	731.6	807.7	490.6	206.0	80.5	0.0	0.0	2316.4
2002	0.0	0.0	0.0	0.0	0.0	1093.8	188.2	835.8	127.8	7.2	0.0	0.0	2252.8
2003	0.0	0.0	0.0	0.0	0.0	709.9	942.2	731.9	284.1	16.0	0.0	0.0	2684.1
2004	0.0	0.0	0.0	0.0	15.3	329.4	729.6	1491.2	78.8	95.0	0.0	0.0	2739.3
2005	0.0	0.0	0.0	0.0	0.0	897.4	851.3	855.5	819.9	6.9	0.0	0.0	3431.0
2006	0.0	0.0	13.3	0.0	17.6	536.8	1289.4	1184.7	193.5	50.8	0.0	0.0	3286.1
2007	0.0	0.0	0.0	0.0	0.0	457.2	753.7	1018.4	425.3	0.0	0.0	0.0	2654.6
2008	0.0	0.0	0.0	0.0	0.8	403.4	1144.4	994.0	335.8	54.0	0.0	0.0	2932.4
2009	0.0	0.0	0.0	0.0	0.0	194.8	1341.4	199.0	156.0	135.0	80.0	0.0	2106.2
2010	0.0	0.0	0.0	0.0	0.0	308.7	1183.8	861.0	490.9	104.4	36.0	0.0	2984.8
2011	0.0	0.0	0.0	0.0	0.0	250.5	1358.9	1156.4	312.0	22.2	0.0	0.0	3100.0
2012	0.0	0.0	0.0	0.0	0.0	214.0	953.8	601.9	353.0	108.4	0.0	0.0	2231.1
2013	0.0	0.0	0.0	0.0	0.0	750.7	1181.1	594.8	399.9	154.4	0.0	0.0	3080.9
2014	0.0	0.0	0.0	0.0	0.0	186.2	1278.4	584.6	457.4	60.4	0.0	0.0	2567.0
2015	0.0	0.0	0.0	0.0	0.0	523.5	615.5	281.5	226.3	44.4	20.6	0.0	1711.8
2016	0.0	0.0	0.0	0.0	0.0	302.0	1206.0	1080.9	344.8	89.7	0.0	0.0	3023.4
2017	0.0	0.0	0.0	0.0	0.0	745.1	1456.1	765.8	319.6	146.2	0.0	80.0	3512.8
2018	0.0	0.0	1.0	0.0	0.8	494.2	1753.0	478.0	52.4	9.5	0.0	0.0	2788.9
2019	0.0	0.0	0.0	0.0	0.0	361.3	1478.1	880.1	856.8	84.5	25.3	1.0	3687.1
Mean	0.0	0.0	0.7	0.0	5.9	471.3	1071.9	756.7	347.0	73.8	8.0	3.7	2738.9
SD	0.0	0.0	2.8	0.0	14.8	257.4	341.8	323.1	233.8	51.3	19.0	17.0	514.3
CV (%)	-	-	435.9	-	252.2	54.6	31.9	42.7	67.4	69.5	237.1	463.0	18.8

During this 22 year period, the highest mean rainfall of 1071.9 mm occurred in the month of July, followed by August (756.7 mm), June (471.3 mm), September (347.0 mm) while the months of October, November, May, December and March experienced relatively low rainfall (73.8 mm, 8.0 mm, 6.6 mm, 5.9 mm, 3.7 mm and 0.7 mm, respectively). There was no rain in the months of January, February and April during period of 1998-2019 in Vikramgad tehsil. The monthly coefficient of variation value varies from 31.9 % to 463.0 %. It showed that coefficient of variation of monsoon months (June to September) were lower than other months.

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4) *Monthly Rainfall analysis of Wada Tehsil:* Table 4 showed that monthly rainfall analysis of Wada tehsil during 1998-2019 over a 22 year period. The result showed that highest rainfall occurred in the month of July in 17 years out of the 22 years, followed by the month of June (2 years), August (2 years) and September (1 years). During this 22 year period, the highest mean rainfall of 998.5 mm occurred in the month of July, followed by August (720.3 mm), June (485.9 mm), September (378.9 mm) while the months of October, November, May, December and March experienced relatively low rainfall (73.7 mm, 9.5 mm, 5.4 mm, 1.7 mm and 0.2 mm, respectively). There was no rain in the months of January, February and April during period of 1998-2019 in Wada tehsil.

Table 4: Monthly variation of mean rainfall (mm) of Wada tehsil during 1998-2019

Year	Jan.	Feb.	March	April	May	June	July	August	Sept.	Octo.	Nov.	Dec.	Annual Rainfall
1998	0.0	0.0	0.0	0.0	0.0	257.2	673.1	677.0	845.1	203.5	50.0	0.0	2705.9
1999	0.0	0.0	0.0	0.0	0.0	479.6	816.0	243.2	342.2	160.2	0.0	0.0	2041.2
2000	0.0	0.0	0.0	0.0	107.2	414.2	1468.0	816.2	118.2	86.2	0.0	0.0	3010.0
2001	0.0	0.0	0.0	0.0	0.0	840.6	805.6	454.0	208.1	53.6	0.0	0.0	2361.9
2002	0.0	0.0	0.0	0.0	0.0	1574.4	303.0	963.3	326.0	0.0	0.0	0.0	3166.7
2003	0.0	0.0	0.0	0.0	0.0	506.1	928.1	665.8	267.2	21.0	0.0	0.0	2388.2
2004	0.0	0.0	0.0	0.0	0.0	307.4	739.4	1335.3	164.2	22.0	0.0	0.0	2568.3
2005	0.0	0.0	0.0	0.0	0.0	692.2	932.8	763.6	912.1	4.0	0.0	0.0	3304.7
2006	0.0	0.0	3.0	0.0	7.0	508.4	1227.6	1123.2	318.9	90.0	0.0	0.0	3278.1
2007	0.0	0.0	0.0	0.0	0.0	449.9	583.0	1004.2	502.0	0.0	0.0	0.0	2539.1
2008	0.0	0.0	0.0	0.0	4.0	454.2	1013.1	876.0	554.0	3.0	0.0	0.0	2904.3
2009	0.0	0.0	0.0	0.0	0.0	116.2	1104.8	172.0	133.0	226.0	23.0	0.0	1775.0
2010	0.0	0.0	0.0	0.0	0.0	237.0	1046.5	841.5	365.5	130.0	60.0	0.0	2680.5
2011	0.0	0.0	0.0	0.0	0.0	215.0	1173.0	1127.0	310.0	61.0	0.0	0.0	2886.0
2012	0.0	0.0	0.0	0.0	0.0	199.2	617.0	532.0	467.0	99.0	0.0	0.0	1914.2
2013	0.0	0.0	0.0	0.0	0.0	849.0	1275.4	489.2	386.6	119.5	0.0	0.0	3119.7
2014	0.0	0.0	0.0	0.0	0.0	57.2	1315.4	627.3	358.6	16.6	0.0	0.0	2375.1
2015	0.0	0.0	0.0	0.0	0.0	507.6	765.8	271.7	225.5	58.0	41.3	0.0	1869.9
2016	0.0	0.0	0.0	0.0	0.0	238.3	1057.1	854.4	244.9	64.7	0.0	0.0	2459.4
2017	0.0	0.0	0.0	0.0	0.0	760.8	1168.4	693.5	382.9	100.5	0.0	33.0	3139.1
2018	0.0	0.0	0.3	0.0	0.4	548.4	1292.7	294.5	52.7	10.8	0.0	0.0	2199.8
2019	0.0	0.0	0.0	0.0	0.0	477.2	1662.0	1021.7	851.4	91.0	33.9	4.3	4141.5
Mean	0.0	0.0	0.2	0.0	5.4	485.9	998.5	720.3	378.9	73.7	9.5	1.7	2674.0
SD	0.0	0.0	0.6	0.0	22.8	327.8	320.9	315.4	234.6	65.2	18.9	7.1	568.5
CV (%)	-	-	426.5	-	423.0	67.5	32.1	43.8	61.9	88.5	199.9	415.9	21.3

The monthly coefficient of variation value varies from 32.1% to 426.5 %. It showed that coefficient of variation of monsoon months (June to September) were lower than other months.

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5) Monthly Rainfall analysis of Talasari Tehsil

Table 5: Monthly variation of mean rainfall (mm) of Talasari tehsil during 1998-2019

Year	Jan.	Feb.	March	April	May	June	July	August	Sept.	Octo.	Nov.	Dec.	Annual Rainfall
1998	0.0	0.0	0.0	0.0	0.0	323.4	609.6	382.4	996.4	109.0	31.2	0.0	2452.0
1999	0.0	0.0	0.0	0.0	19.0	468.8	558.2	297.6	367.5	216.0	0.0	0.0	1927.1
2000	0.0	0.0	0.0	0.0	71.0	357.3	1695.0	455.0	44.7	8.0	0.0	10.0	2641.0
2001	0.0	0.0	0.0	0.0	0.0	592.8	655.6	740.8	156.1	74.7	0.0	0.0	2220.0
2002	0.0	17.1	0.0	0.0	0.0	1207.6	249.9	702.0	46.5	0.0	0.0	5.0	2228.1
2003	0.0	0.0	0.0	0.0	0.0	466.0	786.5	750.2	183.2	12.5	0.0	0.0	2198.4
2004	0.0	0.0	0.0	0.0	54.0	386.4	878.0	1162.0	93.2	31.5	0.0	0.0	2605.1
2005	0.0	0.0	0.0	0.0	0.0	891.6	625.3	530.7	654.1	3.0	0.0	0.0	2704.7
2006	0.0	0.0	14.0	0.0	0.1	474.0	1153.3	1017.3	258.0	35.0	0.0	0.0	2951.7
2007	0.0	0.0	0.0	0.0	0.0	527.5	751.5	988.0	489.5	0.0	0.0	0.0	2756.5
2008	0.0	0.0	0.0	0.0	2.0	384.9	910.0	948.0	333.0	32.0	0.0	0.0	2609.9
2009	0.0	0.0	0.0	0.0	0.0	92.0	1490.0	343.0	166.0	112.0	85.0	0.0	2288.0
2010	0.0	0.0	0.0	0.0	0.0	257.0	1220.0	1069.0	702.8	108.2	86.0	0.0	3443.0
2011	0.0	0.0	0.0	0.0	0.0	217.0	1340.4	1282.0	395.0	2.0	0.0	0.0	3236.4
2012	0.0	0.0	0.0	0.0	0.0	157.0	616.0	488.0	668.0	68.0	0.0	0.0	1997.0
2013	0.0	0.0	0.0	0.0	0.0	852.0	1094.0	618.0	505.9	136.5	0.0	0.0	3206.4
2014	0.0	0.0	0.0	0.0	0.0	105.5	1461.4	565.5	523.5	5.5	0.0	0.0	2661.4
2015	0.0	0.0	0.0	0.0	0.0	404.5	718.9	248.3	175.0	0.0	36.5	0.0	1583.2
2016	0.0	0.0	0.0	0.0	0.0	262.6	1274.3	925.0	551.0	57.0	0.0	0.0	3069.9
2017	0.0	0.0	0.0	0.0	0.0	904.5	1369.1	774.2	292.9	123.1	0.0	86.4	3550.2
2018	0.0	0.0	0.0	0.0	0.0	634.5	1567.1	382.8	42.2	0.0	0.0	0.0	2626.6
2019	0.0	0.0	0.0	0.0	0.0	303.5	1290.8	620.5	666.4	62.4	29.8	2.4	2975.8
Mean	0.0	0.8	0.6	0.0	6.6	466.8	1014.3	695.0	377.8	54.4	12.2	4.7	2633.3
SD	0.0	3.6	3.0	0.0	18.7	285.2	394.7	297.0	260.4	58.7	26.3	18.4	502.5
CV (%)	-	-	469.0	-	281.7	61.1	38.9	42.7	68.9	107.9	215.6	389.9	19.1

Table 5 showed that monthly rainfall analysis of Talasari tehsil during 1998-2019 over a 22 year period. The result showed that highest rainfall occurred in the month of July in 14 years out of the 22 years, followed by the month of August (4 years), June (2 years) and September (2 years). During this 22 year period, the highest mean rainfall of 1014.3 mm occurred in the month of July, followed by August (695.0 mm), June (466.8 mm), September (377.8 mm) while the months of October, November, May, December, February and March experienced relatively low rainfall (54.4 mm, 12.2 mm, 6.6 mm, 4.7 mm, 0.8 mm and 0.6 mm, respectively). There was no rain in the months of January and April during period of 1998-2019 in Talasari tehsils. The monthly coefficient of variation value varies from 38.9 % to 469.0 %. It showed that coefficient of variation of monsoon months (June to September) were lower than other months.

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6) Monthly Rainfall analysis of Palghar Tehsil

Table 6: Monthly variation of mean rainfall (mm) of Palghar tehsil during 1998-2019

Year	Jan.	Feb.	March	April	May	June	July	August	Sept.	Octo.	Nov.	Dec.	Annual Rainfall
1998	0.0	0.0	0.0	0.0	0.0	243.4	835.3	679.7	1477.0	287.0	15.0	0.0	3537.4
1999	0.0	0.0	0.0	0.0	0.0	302.0	464.9	145.6	352.0	78.9	0.0	0.0	1343.4
2000	0.0	0.0	0.0	0.0	207.6	256.0	1378.4	513.1	45.9	10.0	0.0	0.0	2411.0
2001	0.0	0.0	0.0	0.0	0.0	786.4	813.7	738.0	246.9	25.2	0.0	0.0	2610.2
2002	0.0	0.0	0.0	0.0	0.0	986.2	139.7	916.6	53.1	6.0	0.0	0.0	2101.6
2003	0.0	0.0	0.0	0.0	0.0	585.4	934.4	450.7	305.0	11.4	0.0	0.0	2286.9
2004	0.0	0.0	0.0	0.0	0.0	260.6	703.2	1133.0	58.4	51.5	0.0	0.0	2206.7
2005	0.0	0.0	0.0	0.0	0.0	752.0	706.2	701.8	758.0	79.0	0.0	0.0	2997.0
2006	0.0	0.0	17.1	0.0	31.0	463.6	901.2	735.4	381.4	81.2	0.0	0.0	2610.9
2007	0.0	0.0	0.0	0.0	0.0	409.8	563.5	740.8	312.8	0.0	0.0	0.0	2026.9
2008	0.0	0.0	0.0	0.0	4.6	554.8	1018.9	843.3	360.8	5.6	0.0	0.0	2788.0
2009	0.0	0.0	0.0	0.0	0.0	347.1	1436.7	338.4	347.2	176.7	73.7	0.0	2719.8
2010	0.0	0.0	0.0	0.0	0.0	521.8	1186.8	940.4	314.8	109.0	97.1	0.0	3169.9
2011	0.0	0.0	0.0	0.0	0.0	202.1	1127.9	623.2	303.6	40.6	0.0	0.0	2297.4
2012	0.0	0.0	0.0	0.0	0.0	187.6	672.0	469.0	656.5	32.2	0.0	0.0	2017.3
2013	0.0	0.0	0.0	0.0	0.0	1149.2	1026.6	362.4	285.7	150.4	0.0	0.0	2974.3
2014	0.0	0.0	0.0	0.0	0.0	65.3	1418.3	547.8	146.8	5.5	0.0	0.0	2183.7
2015	0.0	0.0	0.0	0.0	0.0	669.2	728.5	148.5	293.6	12.8	0.0	0.0	1852.6
2016	0.0	0.0	0.0	0.0	0.0	725.6	1150.7	764.9	760.1	110.6	0.0	0.0	3511.9
2017	0.0	0.0	0.0	0.0	0.0	692.7	916.2	714.8	384.7	104.2	0.0	90.2	2902.8
2018	0.0	0.0	0.1	0.0	0.1	622.9	1406.7	210.2	22.4	0.0	0.0	0.0	2262.4
2019	0.0	0.0	0.0	0.0	0.0	504.3	1342.1	710.0	1066.3	58.3	64.8	0.2	3746.0
Mean	0.0	0.0	0.8	0.0	11.1	513.1	948.7	610.3	406.0	65.3	11.4	4.1	2570.8
SD	0.0	0.0	3.6	0.0	44.4	273.6	342.5	260.1	350.8	71.2	28.0	19.2	597.2
CV (%)	-	-	466.2	-	401.4	53.3	36.1	42.6	86.4	109.0	245.6	468.0	23.2

Table 6 showed that monthly rainfall analysis of Palghar tehsil during 1998-2019 over a 22 year period. The result showed that highest rainfall occurred in the month of July in 16 years out of the 22 years, followed by the month of June (3 years), August (2 years) and September (1 year). During this 22 year period, the highest mean rainfall of 948.7 mm occurred in the month of July, followed by August (610.3 mm), June (513.1 mm), September (406.0 mm) while the months of October, November, May, December and March experienced relatively low rainfall (65.3 mm, 11.4 mm, 11.1 mm, 4.1 mm and 0.8 mm, respectively). There was no rain in the months of January, February and April during period of 1998-2019 in Palghar tehsil.

The monthly coefficient of variation value varies from 36.1 % to 466.2 %. It showed that coefficient of variation of monsoon months (June to September) were lower than other months.

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7) Monthly Rainfall analysis of Mokhada Tehsil

Table 7: Monthly variation of mean rainfall (mm) of Mokhada tehsil during 1998-2019

Year	Jan.	Feb.	March	April	May	June	July	August	Sept.	Octo.	Nov.	Dec.	Annual Rainfall
1998	0.0	0.0	0.0	0.0	0.0	247.9	640.9	656.5	648.6	249.8	53.5	0.0	2497.2
1999	0.0	0.0	0.0	0.0	0.0	457.7	992.9	306.8	221.2	332.9	0.0	0.0	2311.5
2000	0.0	0.0	0.0	0.0	69.4	150.1	866.7	463.7	78.1	75.7	0.0	0.0	1703.7
2001	0.0	0.0	0.0	0.0	0.0	729.7	668.0	400.8	77.2	92.5	0.0	0.0	1968.2
2002	0.0	0.0	0.0	0.0	0.0	1125.6	310.9	699.3	116.9	62.1	0.8	0.0	2315.6
2003	0.0	0.0	0.0	0.0	0.0	665.2	797.3	588.6	348.7	0.0	19.0	0.0	2418.8
2004	0.0	0.0	0.0	0.0	0.0	522.2	609.6	1843.2	140.3	55.4	0.0	0.0	3170.7
2005	0.0	0.0	0.0	0.0	0.0	767.7	903.9	714.8	819.4	38.9	0.0	0.0	3244.7
2006	0.0	0.0	5.4	0.0	0.0	316.8	1279.7	1246.3	250.8	86.4	0.0	0.0	3185.4
2007	0.0	0.0	0.0	0.0	0.0	455.8	700.0	959.5	448.1	0.0	0.0	0.0	2563.4
2008	0.0	0.0	0.0	0.0	4.6	330.1	872.6	1018.0	573.0	53.4	0.0	0.0	2851.7
2009	0.0	0.0	0.0	0.0	0.0	113.2	1387.9	167.0	130.0	188.0	81.0	0.0	2067.1
2010	0.0	0.0	0.0	0.0	0.0	220.0	844.1	748.0	428.0	190.0	64.0	0.0	2494.1
2011	0.0	0.0	0.0	0.0	0.0	301.3	863.1	1102.4	389.2	81.8	0.0	0.0	2737.8
2012	0.0	0.0	0.0	0.0	0.0	211.7	816.7	481.4	365.0	120.4	0.0	0.0	1995.2
2013	0.0	0.0	0.0	0.0	0.0	433.4	1231.0	707.5	364.0	84.7	0.0	0.0	2820.6
2014	0.0	0.0	0.0	0.0	0.0	149.2	895.1	477.1	512.1	42.5	0.0	0.0	2076.0
2015	0.0	0.0	0.0	0.0	0.0	386.2	685.4	333.6	268.2	76.2	16.0	0.0	1765.6
2016	0.0	0.0	0.0	0.0	0.0	189.4	1165.5	1058.0	181.4	70.9	0.0	0.0	2665.2
2017	0.0	0.0	0.0	0.0	0.0	632.2	1435.0	756.5	281.2	146.5	0.0	16.9	3268.3
2018	0.0	0.0	1.7	0.0	0.0	283.6	1482.5	491.9	56.3	4.1	0.0	0.0	2320.1
2019	0.0	0.0	0.0	0.0	0.0	226.9	1442.7	1176.5	587.8	61.9	22.7	0.0	3518.5
Mean	0.0	0.0	0.3	0.0	3.4	405.3	949.6	745.3	331.2	96.1	11.7	0.8	2543.6
SD	0.0	0.0	1.2	0.0	14.8	251.2	316.2	385.8	207.0	81.9	23.6	3.6	514.6
CV (%)	-	-	368.9	-	439.5	62.0	33.3	51.8	62.5	85.2	201.6	469.0	20.2

Table 7 showed that monthly rainfall analysis of Mokhada tehsil during 1998-2019 over a 22 year period. It can also be observed that the highest rainfall occurred in the month of July in 16 years out of the 22 years, followed by the month of August (5 years) and September (1 year). During this 22 year period, the highest mean rainfall of 949.6 mm occurred in the month of July, followed by August (745.3 mm), June (405.3 mm), September (331.2 mm) while the months of October, November, May, December and March experienced relatively low rainfall (96.1 mm, 11.7 mm, 3.4 mm, 0.8 mm and 0.3 mm, respectively).

There was no rain in the months of January, February and April during period of 1998-2019 in Mokhada tehsil. The monthly coefficient of variation value varies from 33.3 % to 469.0 %. It showed that coefficient of variation of monsoon months (June to September) were lower than other months.

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8) Monthly Rainfall analysis of Dahanu Tehsil

Table 8: Monthly variation of mean rainfall (mm) of Dahanu tehsil during 1998-2019

Year	Jan.	Feb.	March	April	May	June	July	August	Sept.	Octo.	Nov.	Dec.	Annual Rainfall
1998	0.0	0.0	0.0	0.0	0.0	504.9	503.4	416.4	644.0	259.4	0.0	0.0	2328.1
1999	0.0	0.0	0.0	0.0	32.6	446.7	393.1	169.5	186.1	78.0	0.0	0.0	1306.0
2000	0.0	0.0	0.0	0.0	95.4	73.4	845.1	546.3	37.5	38.2	0.0	1.2	1637.1
2001	2.1	0.0	0.0	0.0	0.0	627.0	500.6	654.4	122.0	8.4	0.0	0.0	1914.5
2002	0.0	0.0	2.5	0.0	2.8	1272.7	85.1	680.6	33.7	0.2	0.0	0.0	2077.6
2003	0.0	0.0	0.0	0.0	0.0	569.4	864.3	464.4	204.3	0.0	0.0	0.0	2102.4
2004	0.0	0.0	0.0	0.0	13.9	230.3	557.9	771.7	71.9	36.9	0.0	0.0	1682.6
2005	0.0	0.0	0.0	0.0	0.0	566.3	641.3	521.6	687.7	16.0	0.0	0.0	2432.9
2006	0.0	0.0	3.8	0.0	37.9	527.3	706.1	788.5	330.1	27.2	0.0	0.0	2420.9
2007	0.0	0.0	0.0	0.0	0.0	332.4	519.4	911.2	347.1	0.0	0.0	0.0	2110.1
2008	0.0	0.0	0.0	0.0	4.8	484.8	738.1	755.7	311.1	0.0	0.0	0.0	2294.5
2009	0.0	0.0	0.0	0.0	0.0	319.9	1815.4	193.1	303.7	104.0	45.6	0.0	2781.7
2010	0.0	0.0	0.0	0.0	0.0	630.8	1051.2	683.7	379.8	27.9	67.0	0.0	2840.4
2011	0.0	0.0	0.0	0.0	0.0	118.2	952.4	782.9	318.4	25.2	0.0	0.0	2197.1
2012	0.0	0.0	0.0	0.0	0.0	151.6	482.8	328.1	836.0	26.7	0.0	0.0	1825.2
2013	0.0	0.0	0.0	0.0	0.0	757.0	1048.5	535.8	405.2	96.0	0.0	0.0	2842.5
2014	0.0	0.0	0.0	0.0	0.0	111.7	1315.9	440.4	341.8	9.5	0.0	0.0	2219.3
2015	0.0	0.0	0.0	0.0	0.0	606.2	596.1	214.4	201.2	25.6	38.4	0.0	1681.9
2016	0.0	0.0	0.0	0.0	0.0	525.9	1097.0	926.1	955.5	103.9	0.0	0.0	3608.4
2017	0.0	0.0	0.1	0.0	0.0	671.5	1238.2	671.9	365.3	80.0	0.0	92.1	3119.1
2018	0.0	0.0	0.0	0.0	1.3	626.7	1350.1	284.4	31.0	34.0	0.0	0.0	2327.5
2019	0.0	0.0	0.0	0.0	0.0	385.5	1213.4	580.4	974.2	51.4	52.2	1.0	3258.1
Mean	0.1	0.0	0.3	0.0	8.6	479.1	841.6	560.1	367.6	47.7	9.2	4.3	2318.5
SD	0.4	0.0	0.9	0.0	22.0	267.6	398.7	226.4	284.1	58.2	20.6	19.6	571.2
CV (%)	469.0	-	325.6	-	257.0	55.8	47.4	40.4	77.3	122.2	222.8	457.6	24.6

Table 8 showed that monthly rainfall analysis of Dahanu tehsil during 1998-2019 over a 22 year period. It can also be observed that the highest rainfall occurred in the month of July in 12 years out of the 22 years, followed by the month of August (5 years), June (4 years) and September (1 years). During this 22 year period, the highest mean rainfall of 841.6 mm occurred in the month of July, followed by August (560.1 mm), June (479.1 mm), September (367.6 mm) while the months of October, November, May, December, March and January experienced relatively low rainfall (47.7 mm, 9.2 mm, 8.6 mm, 4.3 mm, 0.3 mm and 0.1 mm, respectively). There was no rain in the months of February and April during period of 1998-2019 in Dahanu tehsil. The monthly coefficient of variation value varies from 40.4 % to 469.0 %. It showed that coefficient of variation of Monsoon months (June to September) were lower than other months.

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B. Tehsils wise Seasonal Rainfall Analysis

1) Seasonal Analysis of Vasai Tehsil

Table 9: Season wise Mean Rainfall contribution of Vasai tehsil during period of 1998 to 2019

Season	Winter		Pre Monsoon			Monsoon				Post Monsoon			Total Rainfall (mm)
Months	Jan.	Feb.	March	April	May	June	July	August	Sept.	Octo.	Nov.	Dec.	
Mean Rainfall	0.0	0.0	1.7	0.0	25.9	628.9	1009.9	660.8	428.1	86.4	10.9	3.4	2855.9
Total Rainfall	0.0		27.6			2727.7				100.7			
Rainfall (%)	0.0	0.0	0.1	0.0	0.9	22.0	35.4	23.1	15.0	3.0	0.4	0.1	100 %
Total (%)	0.0		1.0 %			95.5 %				3.5 %			

The Monsoon season was contributing 95.5 % annual rainfall in Vasai tehsil during period of 1998-2019. The winter, Pre Monsoon and Post Monsoon season contribute 0.0 %, 1.0 % and 3.5 % of annual rainfall respectively. The rainfall of July month was the highest and contributes 35.4 % of annual rainfall (1009.9 mm, percentage to annual). The June and August rainfalls were almost same and they contribute 22.0 % and 23.1 % of annual rainfall respectively. The month of September was contributing 15.0 % of annual rainfall during 1998-2019 in Vasai Tehsils.

2) Seasonal Rainfall analysis of Jawhar Tehsil

Table 10: Season wise Mean Rainfall contribution of Jawhar tehsil during period of 1998 to 2019

Season	Winter		Pre Monsoon			Monsoon				Post Monsoon			Total Rainfall (mm)
Months	Jan.	Feb.	March	April	May	June	July	August	Sept.	Octo.	Nov.	Dec.	
Mean Rainfall	0.0	0.0	0.2	0.0	2.8	406.7	1147.1	835.6	365.1	68.1	12.6	1.0	2839.2
Total Rainfall	0.0		3.0			2754.5				81.7			
Rainfall (%)	0.0	0.0	0.0	0.0	0.1	14.3	40.4	29.4	12.9	2.5	0.4	0.1	100 %
Total (%)	0.0		0.1 %			97.0 %				2.9 %			

The Monsoon season was contributing 97.0 % annual rainfall in Jawhar tehsil during period of 1998-2019. The winter, Pre Monsoon and Post Monsoon season contribute 0.0 %, 0.1 % and 2.9 % of annual rainfall respectively. The rainfall of July month was the highest and contributes 40.4 % of annual rainfall (1147.1 mm, percentage to annual rainfall). The month of August was contributing 29.4 % of annual rainfall during 1998-2019 in Jawhar Tehsils. The June and September rainfalls were almost same and they contribute 14.3 % and 12.9 % of annual rainfall respectively.

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3) Seasonal Rainfall analysis of Vikramgad Tehsil

Table 11: Season wise Mean Rainfall contribution of Vikramgad tehsil during period of 1998 to 2019

Season	Winter		Pre Monsoon			Monsoon				Post Monsoon			Total Rainfall (mm)
Months	Jan.	Feb.	March	April	May	June	July	August	Sept.	Octo.	Nov.	Dec.	
Mean Rainfall	0.0	0.0	0.7	0.0	5.9	471.3	1071.9	756.7	347.0	73.8	8.0	3.7	2738.9
Total Rainfall	0.0		6.5			2646.9				85.5			
Rainfall (%)	0.0	0.0	0.0	0.0	0.2	17.2	39.1	27.6	12.7	2.7	0.3	0.1	100 %
Total (%)	0.0 %		0.24 %			96.64 %				3.12 %			

The Monsoon season was contributing 96.64 % annual rainfall in Vikramgad tehsil during period of 1998-2019. The winter, Pre Monsoon and Post Monsoon season contribute 0.0 %, 0.24 % and 3.12 % of annual rainfall respectively. The rainfall of July month was the highest and contributes 39.1 % of annual rainfall (1071.9 mm, percentage to annual rainfall). The month of August was contributing 27.6 % of annual rainfall during 1998-2019 in Vikramgad tehsil. The June and September rainfalls were almost same and they contribute 17.2 % and 12.7 % of annual rainfall respectively.

4) Seasonal Rainfall analysis of Wada Tehsil

Table 12: Season wise Mean Rainfall contribution of Wada tehsil during period of 1998 to 2019

Season	Winter		Pre Monsoon			Monsoon				Post Monsoon			Total Rainfall (mm)
Months	Jan.	Feb.	March	April	May	June	July	August	Sept.	Octo.	Nov.	Dec.	
Mean Rainfall	0.0	0.0	0.2	0.0	5.4	485.9	998.5	720.3	378.9	73.7	9.5	1.7	2674.0
Total Rainfall	0.0		5.5			2583.7				84.8			
Rainfall (%)	0.0	0.0	0.0	0.0	0.2	18.2	37.3	26.9	14.2	2.8	0.4	0.1	100 %
Total (%)	0.0		0.2			96.6				3.2			

The Monsoon season was contributing 96.6 % annual rainfall in Wada tehsil during period of 1998-2019. The winter, Pre Monsoon and Post Monsoon season contribute 0.0 %, 0.2 % and 3.2 % of annual rainfall respectively. The rainfall of July month was the highest and contributes 37.3 % of annual rainfall (998.5 mm, percentage to annual rainfall). The month of August was contributing 26.9 % of annual rainfall during 1998-2019 in Wada tehsil. The June and September rainfalls were almost same and they contribute 18.2 % and 14.2 % of annual rainfall respectively.

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5) Seasonal Rainfall Analysis of Talasari Tehsils

Table 13: Season wise Mean Rainfall contribution of Talasari tehsil during period of 1998 to 2019

Season	Winter		Pre Monsoon			Monsoon				Post Monsoon			Total Rainfall (mm)
Months	Jan.	Feb.	March	April	May	June	July	August	Sept.	Octo.	Nov.	Dec.	
Mean Rainfall	0.0	0.8	0.6	0.0	6.6	466.8	1014.3	695.0	377.8	54.4	12.2	4.7	2633.3
Total Rainfall	0.8		7.2			2553.9				71.3			
Rainfall (%)	0.0	0.0	0.0	0.0	0.3	17.7	38.5	26.4	14.3	2.1	0.5	0.2	100 %
Total (%)	0.03 %		0.27 %			97.0 %				2.7 %			

The Monsoon season was contributing 97.0% annual rainfall in Talasari tehsil during period of 1998-2019. The winter, Pre Monsoon and Post Monsoon season contribute 0.0 %, 0.27 % and 2.7 % of annual rainfall respectively. The rainfall of July month was the highest and contributes 38.5 % of annual rainfall (1014.3 mm, percentage to annual rainfall). The month of August was contributing 26.4 % of annual rainfall during 1998-2019 in Talasari tehsil. The June and September rainfalls were almost same and they contribute 17.7 % and 14.3 % of annual rainfall respectively.

6) Seasonal Rainfall analysis of Palghar Tehsils

Table 14: Season wise Mean Rainfall contribution of Palghar tehsil during period of 1998 to 2019

Season	Winter		Pre Monsoon			Monsoon				Post Monsoon			Total Rainfall (mm)
Months	Jan.	Feb.	March	April	May	June	July	August	Sept.	Octo.	Nov.	Dec.	
Mean Rainfall	0.0	0.0	0.8	0.0	11.1	513.1	948.7	610.3	406.0	65.3	11.4	4.1	2570.8
Total Rainfall	0.0		11.8			2478.2				80.8			
Rainfall (%)	0.0	0.0	0.0	0.0	0.4	20.0	36.9	23.7	15.8	2.5	0.4	0.2	100 %
Total (%)	0.0		0.5 %			96.4 %				3.1 %			

The Monsoon season was contributing 96.4 % annual rainfall in Palghar tehsil during period of 1998-2019. The winter, Pre Monsoon and Post Monsoon season contribute 0.0 %, 0.5 % and 3.1 % of annual rainfall respectively. The rainfall of July month was the highest and contributes 36.9 % of annual rainfall (948.7 mm, percentage to annual rainfall). The month of August was contributing 23.7 % of annual rainfall during 1998-2019 in Palghar tehsil. The months of June and September contribute 20.0 % and 15.8 % of annual rainfall respectively.

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7) Seasonal Rainfall analysis of Mokhada Tehsil

Table 15: Season wise Mean Rainfall contribution of Mokhada tehsil during period of 1998 to 2019

Season	Winter		Pre Monsoon			Monsoon				Post Monsoon			Total Rainfall (mm)
Months	Jan.	Feb.	March	April	May	June	July	August	Sept.	Octo.	Nov.	Dec.	
Mean Rainfall	0.0	0.0	0.3	0.0	3.4	405.3	949.6	745.3	331.2	96.1	11.7	0.8	2543.6
Total Rainfall	0.0		3.7			2431.4				108.5			
Rainfall (%)	0.0	0.0	0.0	0.0	0.1	15.9	37.3	29.3	13.0	3.8	0.5	0.0	100 %
Total (%)	0.0		0.1			95.6				4.3			

The Monsoon season was contributing 95.6 % annual rainfall in Mokhada tehsil during period of 1998-2019. The winter, Pre Monsoon and Post Monsoon season contribute 0.0 %, 0.1 % and 4.3 % of annual rainfall respectively. The rainfall of July month was the highest and contributes 37.3 % of annual rainfall (949.6 mm, percentage to annual rainfall). The month of August was contributing 29.3 % of annual rainfall during 1998-2019 in Mokhada tehsil. The June and September rainfalls were almost same and they contribute 15.9 % and 13.0 % of annual rainfall respectively.

8) Seasonal Rainfall analysis of Dahanu Tehsil

Table 16: Season wise Mean Rainfall contribution of Dahanu tehsil during period of 1998 to 2019

Season	Winter		Pre Monsoon			Monsoon				Post Monsoon			Total Rainfall (mm)
Months	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	
Mean Rainfall	0.1	0.0	0.3	0.0	8.6	479.1	841.6	560.1	367.6	47.7	9.2	4.3	2318.5
Total Rainfall	0.1		8.9			2248.4				61.2			
Rainfall (%)	0.0	0.0	0.0	0.0	0.4	20.7	36.3	24.2	15.9	2.1	0.4	0.2	100 %
Total (%)	0.0		0.4			97.0				2.6			

The Monsoon season was contributing 97.0 % annual rainfall in Dahanu tehsil during period of 1998-2019. The winter, Pre Monsoon and Post Monsoon season contribute 0.0 %, 0.4 % and 2.6 % of annual rainfall respectively. The rainfall of July month was the highest and contributes 36.3 % of annual rainfall (841.6 mm, percentage to annual rainfall). The month of August was contributing 24.2 % of annual rainfall during 1998-2019 in Dahanu tehsil. The months June and September contribute 20.7 % and 15.9 % of annual rainfall respectively.

The result showed that contribution of rainfall during Monsoon season ranges from 95.5 % to 97.0 % of the annual total rainfall, contribution of rainfall during Pre-Monsoon ranges form 0.1 % to 1% and contribution of rainfall during Post Monsoon ranges form 2.6 % to 4.3 % in period of 1998 to 2019 for tehsils of Palghar District namely Vasai, Jawhar, Vikramgad, Wada, Talasari, Palghar, Mokhada and Dahanu. In winter season, contribution of rainfall was 0 % because in winter season no rain or very less rain received (1998 to 2019) in tehsils of Palghar District.

Similar kind of study had been conducted by Upadhyaya, H., (2014) in Rajasthan, which conducted that the state receives 91% of its annual rainfall due to the South-West monsoon, which is its principal rainy season. During winter, Pre Monsoon and Post Monsoon seasons received very low rainfall or negligible. In tehsils of Palghar districts receives more than 95 % of annual rainfall due to the Monsoon, so it is called principal rainy season of tehsils of Palghar districts.

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9) Annual Rainfall Analysis

Table 17: Tehsil wise Annual rainfall distribution of Palghar Districts during 1998-2019

Year	Vasai	Jawhar	Vikramgad	Wada	Talasari	Palghar	Mokhada	Dahanu
1998	3208.0	2804.2	2804.4	2705.9	2452.0	3537.4	2497.2	2328.1
1999	2591.5	1618.3	2346.6	2041.2	1927.1	1343.4	2311.5	1306.0
2000	3939.1	1848.2	2014.8	3010.0	2641.0	2411.0	1703.7	1637.1
2001	2706.7	2037.2	2316.4	2361.9	2220.0	2610.2	1968.2	1914.5
2002	2497.0	1773.3	2252.8	3166.7	2228.1	2101.6	2315.6	2077.6
2003	3003.0	3004.2	2684.1	2388.2	2198.4	2286.9	2418.8	2102.4
2004	3195.0	3223.7	2739.3	2568.3	2605.1	2206.7	3170.7	1682.6
2005	3883.8	3810.9	3431.0	3304.7	2704.7	2997.0	3244.7	2432.9
2006	3899.7	3794.5	3286.1	3278.1	2951.7	2610.9	3185.4	2420.9
2007	3423.6	2888.8	2654.6	2539.1	2756.5	2026.9	2563.4	2110.1
2008	3690.0	2993.3	2932.4	2904.3	2609.9	2788.0	2851.7	2294.5
2009	2181.0	2172.0	2106.2	1775.0	2288.0	2719.8	2067.1	2781.7
2010	3170.0	3075.0	2984.8	2680.5	3443.0	3169.9	2494.1	2840.4
2011	2857.6	3932.2	3100.0	2886.0	3236.4	2297.4	2737.8	2197.1
2012	1584.0	2566.9	2231.1	1914.2	1997.0	2017.3	1995.2	1825.2
2013	2417.5	3411.4	3080.9	3119.7	3206.4	2974.3	2820.6	2842.5
2014	2044.3	2538.0	2567.0	2375.1	2661.4	2183.7	2076.0	2219.3
2015	1664.1	1831.3	1711.8	1869.9	1583.2	1852.6	1765.6	1681.9
2016	2942.2	2527.4	3023.4	2459.4	3069.9	3511.9	2665.2	3608.4
2017	2407.5	3696.5	3512.8	3139.1	3550.2	2902.8	3268.3	3119.1
2018	1989.4	3081.7	2788.9	2199.8	2626.6	2262.4	2320.1	2327.5
2019	3535.8	3832.0	3687.1	4141.5	2975.8	3746.0	3518.5	3258.1
Minimum	1584.0	1618.3	1711.8	1775.0	1583.2	1343.4	1703.7	1306.0
Maximum	3939.1	3932.2	3687.1	4141.5	3550.2	3746.0	3518.5	3608.4
Mean	2855.9	2839.1	2738.9	2674.0	2633.3	2570.8	2543.6	2318.5
SD	713.3	736.5	514.3	568.5	502.5	597.2	514.6	571.2
CV (%)	25.0	25.9	18.8	21.3	19.1	23.2	20.2	24.6

The annual average rainfall for the period from 1998 to 2019 was analysed and presented in Table 17 and Figure 1. The average annual rainfall during 1998 to 2019 of Vasai, Jawhar, Vikramgad, Wada, Talasari, Palghar, Mokhada and Dahanu tehsils were 2855.9 mm, 2839.1 mm, 2738.9 mm, 2674.0 mm, 2633.3 mm, 2570.8 mm, 2543.6 mm and 2318.5 mm respectively.

Table 2 showed that the standard deviation values were varied from 502.5 mm to 736.5 mm in tehsils of Palghar district. It was considerably large this indicates that larger variation in rainfall pattern. Table 17 showed highest average rainfall (2855.9 mm) was recorded in Vasai tehsil and lowest rainfall (2318.5 mm) was recorded in Dahanu tehsil.

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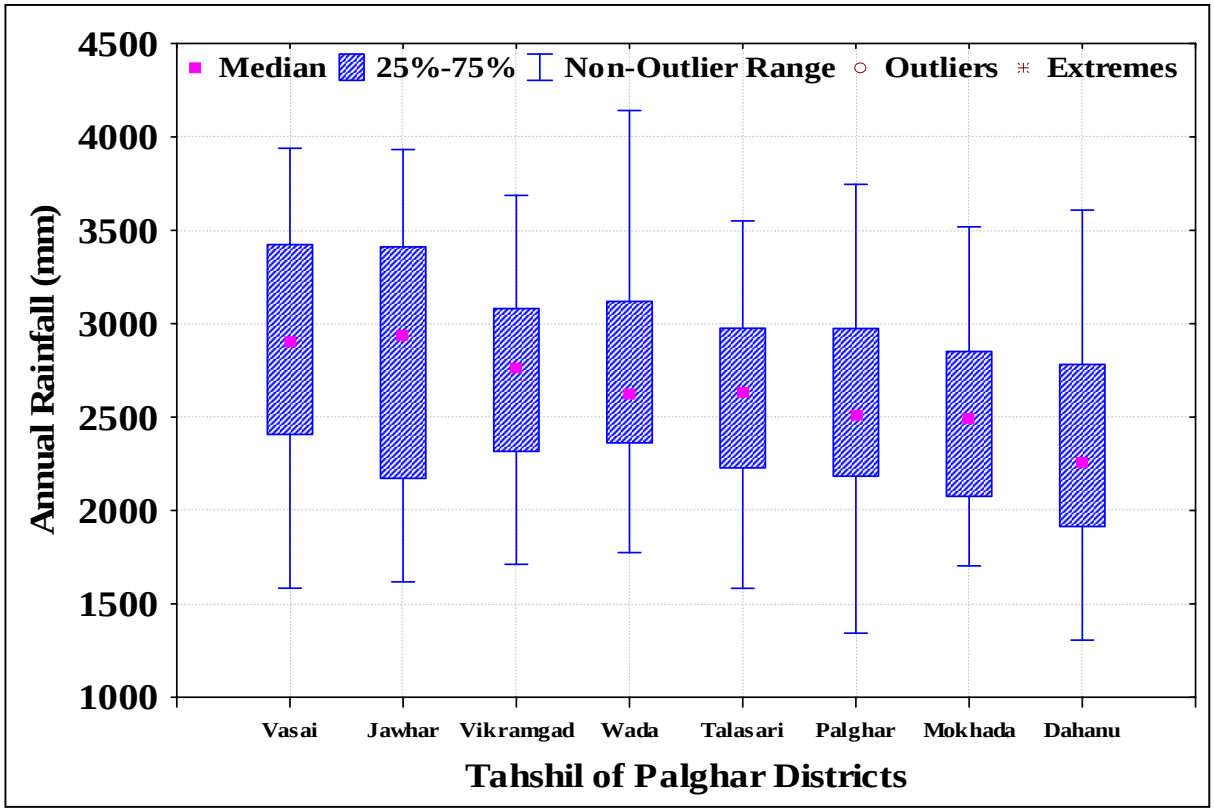


Figure 1: Box and Whisker plot of annual rainfall for tehsils of Palghar districts during 1998 to 2019

In Vasai tehsil highest rainfall occurred in year 2000 (3939.1 mm) followed by year 2006 (3899.7 mm), while the lowest rainfall was in 2012 (1584.0 mm) and that in 2015 (1664.1 mm) being the second lowest. In Jawhar tehsil highest rainfall occurred in year 2019 (3832.0 mm) followed by year 2005 (3832.0 mm), while the lowest rainfall was in year 1999 (1618.3 mm) and that in 2002 (1773.3 mm) being the second lowest. In Vikramgad tehsil highest rainfall was occurred in year 2019 (3687.1 mm) followed by year 2012 (3512.8 mm), while the lowest rainfall was in year 2015 (1711.8 mm) and that in year 2000 (2014.8 mm) being the second lowest. In Wada tehsil highest rainfall was occurred in year 2019 (4141.5 mm) followed by year 2005 (3304.7mm), while the lowest rainfall was in 2009 (1775.0 mm) and that in year 2012 (1914.2 mm) being the second lowest.

In Talasari tehsil highest rainfall was occurred in year 2017 (3550.2 mm) followed by year 2010 (3443.0 mm), while the lowest rainfall was in year 2015 (1583.2 mm) and that in year 1999 (1927.1 mm) being the second lowest. In Palghar tehsil highest rainfall was occurred in year 2019 (3746.0 mm) followed by year 1998 (3537.4 mm), while the lowest rainfall was in year 1999 (1343.4 mm) and that in 2015 (1852.6 mm) being the second lowest. In Mokhada tehsil highest rainfall occurred in year 2019 (3518.5 mm) followed by year 2017 (3268.3 mm), while the lowest rainfall was in year 2000 (1703.7 mm) and that in year 2015 (1765.6 mm) being the second lowest. In Dahanu tehsil highest rainfall was occurred in year 2016 (3608.4 mm) followed by year 2019 (3258.1 mm), while the lowest rainfall was in year 1999 (1306.0 mm) and that in year 2000 (1637.1 mm) being the second lowest. The maximum standard deviation was observed in Jawhar (736.5 mm) followed by Vasai (713.3 mm), Palghar (597.2 mm), Dahanu (571.2 mm), Wada (568.5 mm), Mokhada (514.6 mm), Vikramgad (514.3 mm) and Talasari (502.5mm) with coefficient of variation 25.9 %, 25.0 %, 23.2 %, 24.6 %, 21.3 %, 20.2 %, 18.8 % and 19.1 %, respectively.

IV. CONCLUSION

The daily rainfall data of 22 years (1998 to 2019) was used to access the monthly, seasonal and annual pattern of rainfall. The average annual rainfall (1998 to 2019) of Vasai, Jawhar, Vikramgad, Wada, Talasari, Palghar, Mokhada and Dahanu were 2855.9 mm, 2839.1 mm, 2738.9 mm, 2674.0 mm, 2633.3 mm, 2570.8 mm, 2543.6 mm and 2318.5 mm respectively. It is concluded that tehsils of Palghar Districts were located in heavy rainfall area. The month of July received maximum average rainfall for all years from 1998 to 2019 in tehsils of Palghar district. The result showed that monthly mean rainfall in month of July was maximum at Jawhar (1147.1 mm) followed by Vikramgad (1071.9 mm), Talasari (1014.3 mm), Vasai (1009.9 mm), Wada (998.5 mm), Mokhada

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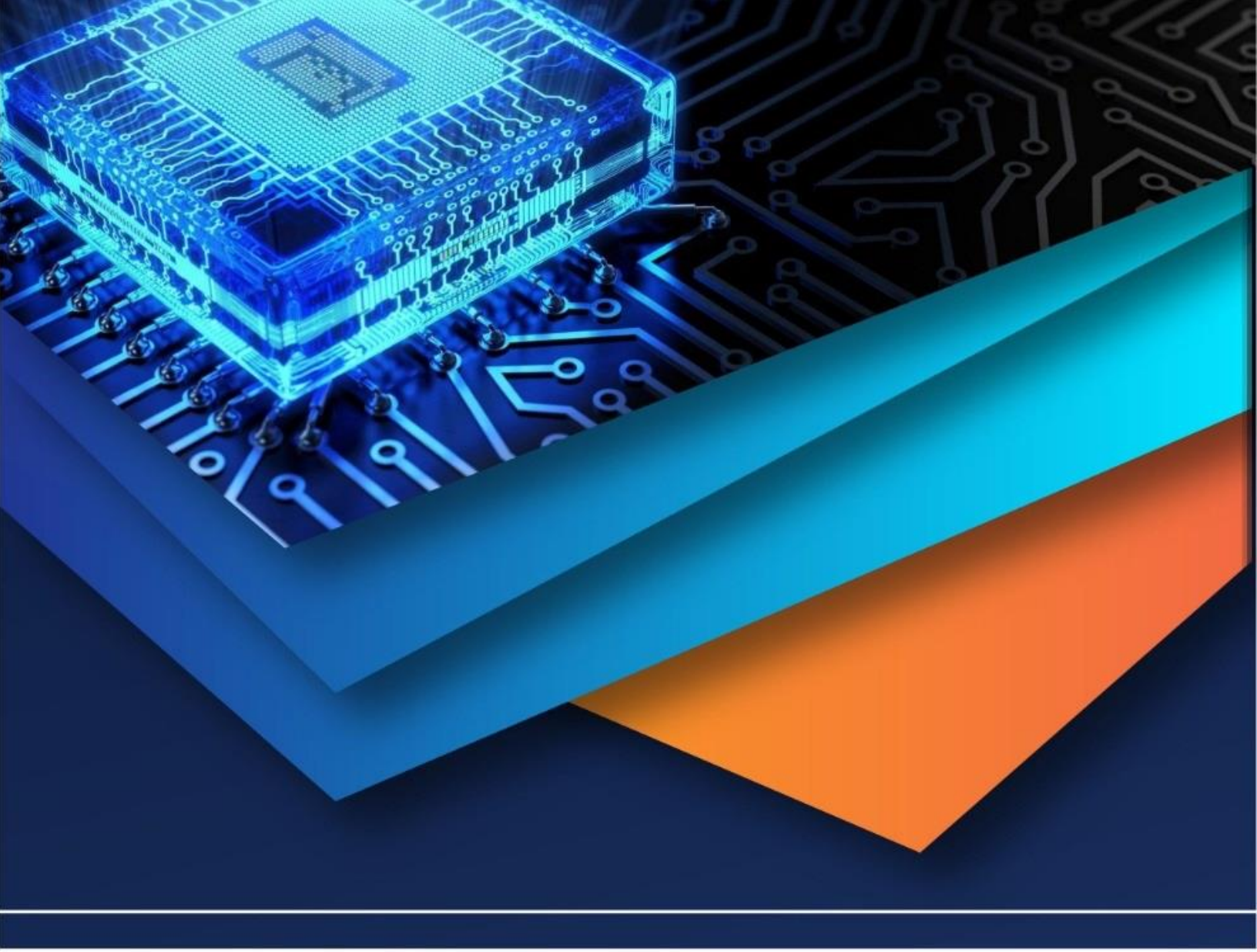
(949.6 mm), Palghar (948.7 mm) and Dahanu (841.6) with contributes 40.4 %, 39.1 %, 38.5 %, 35.4 %, 37.3 %, 37.3 %, 36.9 % and 36.3 % of the annual mean rainfall (1998 to 2019) respectively. It is concluded that tehsils of Palghar districts mainly depend Monsoon Season (June to September). The tehsils of Palghar districts received more than 95 % of annual rainfall due to the Monsoon, so Monsoon season is called principal rainy season for tehsils of Palghar districts. The results showed that winter, Pre-Monsoon and Post-Monsoon seasons received very low rainfall or negligible. Since tehsils of Palghar mainly depends on Monsoon Season, therefore water storage structures may be constructed in these regions in order to increase surface cum groundwater availability. This study suggested that in tehsils of Palghar districts need of preliminary work for designing the soil and water conservation structures, construction of rain water harvesting structure and surface drainage structures is very essential for increase groundwater recharge.

Study is also suggest that construction of farm ponds for storing the Monsoon (June to September) rain water, which will be used for irrigation in Rabi and summer season crops.

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