IJNRD.ORG ISSN : 2456-4184

INTERNATIONAL JOURNAL OF NOVEL RESEARCH AND DEVELOPMENT (IJNRD) | IJNRD.ORG

An International Open Access, Peer-reviewed, Refereed Journal

DETECTING CHANGES IN SEASONAL AND ANNUAL RAINFALL VARIABILITY OVER MAHARASHTRA STATE

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Abstract

The study of average rainfall and its variability at higher spatial scales is significant in a variety of industries including water and agriculture long rainfall data series 19012015 of Maharashtra districts on monthly and seasonal scales are constructed in this work and then average rainfall coefficient of variability standard deviation skewness and kurtosis are analysed to determine the geographical pattern and variability trend analysis of rainfall time series identifies significant long-term changes in monthly rainfall on the district scale seasonal variability which is a measure of the distribution of precipitation over the course of a season is used to categorise the various rainfall regimes the state of Maharashtra is heavily influenced by the southwest monsoon and the state is experiencing a drought this research will aid in determining the possible causes of Maharashtra's escalating water scarcity and drought situations long rainfall data series 19012015 of Maharashtra districts on monthly and seasonal scales are constructed in this study and mean rainfall and coefficient of variability are analysed to determine spatial pattern and variability

***Keywords**: seasonal, annual rainfall variability, CV, SD, Skewness, Kurtosis Maharashtra.*

1.INTRODUCTION

The state of Maharashtra features a diverse physiography as well as climate variations. Because of the state's diverse physiographic and climatic qualities, the India Meteorological Department split it into four meteorological sub-divisions. The meteorological sub-division is Konkan, while Goa lies to the extreme west, extending north-south along India's west coast. Because of this topographical feature, the region receives a lot of rain throughout the monsoon season. The rainfall patterns in Madhya Pradesh, Maharashtra, and Marathwada are nearly identical, with Madhya Pradesh having a slightly greater mean monsoon or annual rainfall. The rainfall patterns are quite variable within seasons. Furthermore, rainfall varies greatly among Maharashtra's districts. Many scholars (Guhathakurta et al. 2011; Sinharay and Srivastava 2000) have observed increasing trends in high rainfall events as well as total rainfall over Madhya Pradesh, Maharashtra, Konkan, and Goa. The Vidarbha area is located in the extreme east of the state; its mean monsoon or annual rainfall is less than that of Konkan and Goa but greater than that of Madhya Pradesh, Maharashtra, and Marathwada. For better disaster management and water resource management and planning, state and district administrations must have state and district rainfall climatology as well as information about the temporal variability of rainfall at the macro and micro levels. However, there has been no comprehensive investigation of district rainfall climatology, variability, and changing rainfall patterns using long-term data. The reason for this is the lack of long-term district rainfall data. In this study, we give the monthly rainfall series for all 35 districts of Maharashtra from 1901 to 2015. The mean rainfall pattern, as well as the variability of the four seasons and yearly rainfall, is provided for each of Maharashtra's 35 districts. This information is extremely beneficial to the state's agriculture and water sectors.

The study's goal is to discover the changing pattern of rainfall over Maharashtra at the district level, which may have an impact on growing extreme rainfall events such as droughts and floods in the state. Precipitation distribution during the seasonal cycle is equally essential. The seasonal distribution of precipitation is caused by the Earth's revolution, which causes unequal heating of the Earth's surface throughout the year, resulting in atmospheric general circulation. The distribution of rainfall throughout the season and year is critical to agriculture and the economy. It is critical to identify historical variations in seasonal and yearly rainfall averages.

I took all 35 districts' data from 1901 to 2015 and divided it again by period for seasonal and temporal rainfall variations. Variability is observed seasonally, yearly, and temporally in practically all Maharashtra districts.

2.STUDY AREA

Maharashtra state is situated at 1530'N-22' latitude and 7230'E-8055' longitude and has an elevation of 1,660 feet. After Rajasthan and Madhya Pradesh, Maharashtra is India's third-largest state by area. It has a land area of 3,07,713 km2 and is bounded to the north by Madhya Pradesh, to the east by Chhattisgarh, to the southeast by Telangana, to the south by Karnataka, and to the southwest by Goa. Gujarat lies to the northwest, with the Union territories of Dadra and Nagar Haveli wedged between the boundaries. Maharashtra has a coastline of 720 kilometres. Maharashtra, located in the north-central region of Peninsular India, commands the Arabian Sea through the port of Mumbai. Maharashtra has remarkable physical homogeneity, which is reinforced by its underlying geology. The state's major physical feature is its plateau character, which includes Maharashtra's western coastal plains, western upturned rims ascending to create the Sahyadri Range, and its slopes gently decreasing to the east and southeast. Maharashtra's west coast is bounded by the Arabian Sea. Maharashtra is divided into two primary relief divisions. The plateau is part of the Deccan plateau and the Kankan coastal strip, which border the Arabian Sea. Water is one of the most significant natural resources as well as a basic human requirement. Despite the fact that water covers 75% of the earth's total area, we can only use 0.5% of the total water on the planet's surface. Water availability is entirely determined by climate, terrain, and geology.

Rainfall is the state's primary source of water. The state has a tropical monsoon climate, with blistering summer temperatures (40 to 48 degrees Celsius) from March onwards giving way to the wet monsoon in early June. The lush green cover of the monsoon season lasts throughout the mild winter. The seasonal rains from the western sea clouds are quite heavy, with over 400 cm of rain falling on Sahyadri crests. The Konkan on the windward side receives significant rainfall, which decreases northward. Rainfall falls to a modest 70 cm east of the Sahyadri. Solapur-Ahmednagar is located in the arid zone. Rainfall has increased marginally; rain generally falls on June 7th in Maharashtra. The highly pulsatory character of the monsoon, with its short spells of rainy weather and long dry breaks, floods, as well as droughts add much to the discomfort of the state economy.

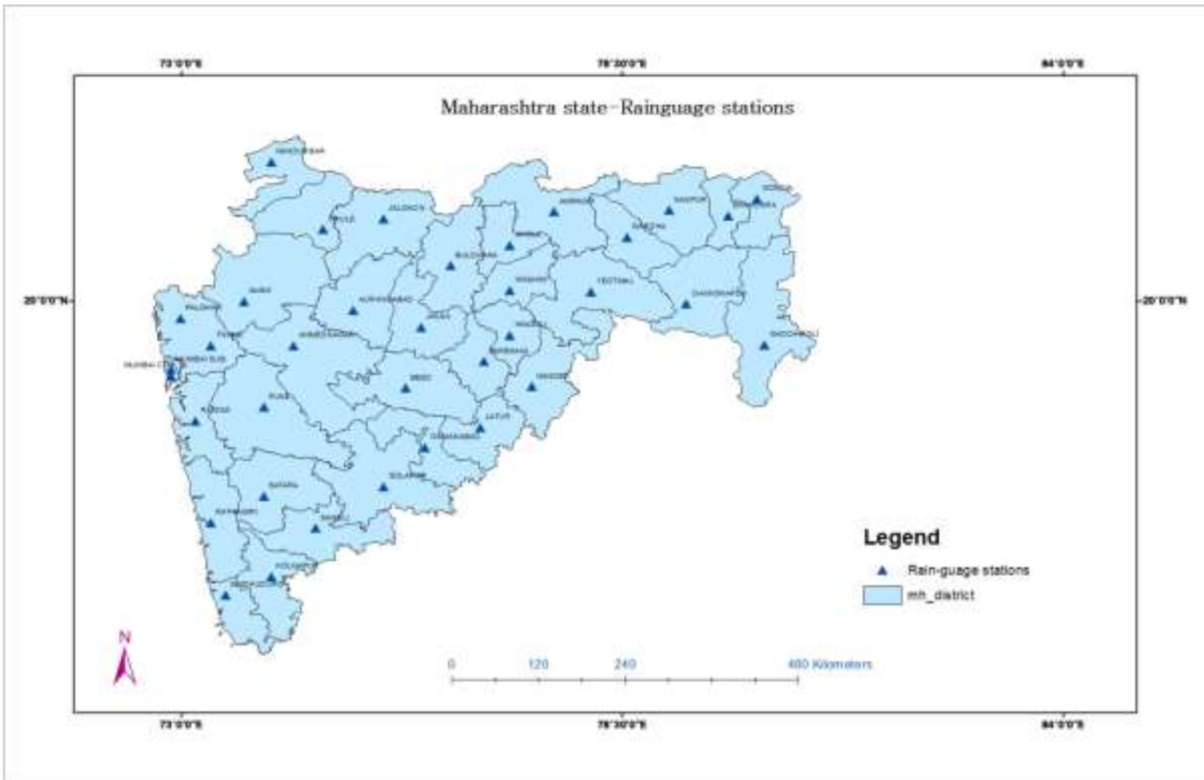

Figure 1. location map of study region

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3.DATA AND METHODOLOGY

3.1 Data construction

From 1901 to 2015, the IITM (Indian Institute of Tropical Meteorology, Pune) gathered monthly rainfall data from about 35 rain gauge stations in the state of Maharashtra. Then, using the arithmetic mean of the monthly precipitation at the stations under each district, the monthly rainfall series of all 35 districts of Maharashtra is calculated. The availability of data for each district is shown in Table 1. For the monthly rainfall time series of 35 districts over the course of a year, the fundamental statistical features are determined.

Table 1. Availability of Rainfall Data

Sr.No.	DISTRICT	Height (Mtrs)	Long.	Lati.	
1	MUMBAI CITY	11	72.49E	18.54N	Rainfall data Availability from 1901 to 2015
2	RAIGAD	3	73.18 E	18.51 N	
3	RATNAGIRI	35	73.20E	16.59N	
4	THANE	7	72.59E	19.12N	
5	SINDHUDURG	22	73.68E	16.28N	
6	MUMBAI SUB	14	72.87E	19.15N	
7	AHMEDNAGAR	649	74.55E	19.05N	
8	DHULE	256	74.47E	20.54N	
9	JALGAON	216	75.34E	21.03N	
10	KOLHAPUR	570	74.14E	16.42N	
11	NASHIK	586	73.47E	20.00N	
12	PUNE	559	73.51E	18.32N	
13	SANGLI	549	74.34E	16.52N	
14	SATARA	727	73.59E	17.41N	
15	SOLAPUR	479	75.54E	17.40N	
16	NANDURBAR	210	74.12E	21.74N	
17	AURANGABAD	581	75.20E	19.53N	
18	BEED	519	75.46E	19.00N	
19	NANDED	358	77.20E	19.08N	
20	OSMANABAD	635	76.03E	18.10N	
21	PARBHANI	423	76.50E	19.08N	
22	LATUR	515	76.70E	18.43N	
23	JALNA	534	75.99E	19.68N	
24	HINGOLI	457	77.10E	19.58N	
25	AKOLA	282	77.02E	20.42N	
26	AMRAVATI	370	77.47E	20.56N	
27	BHANDARA	255	79.40E	21.10N	
28	BULDHANA	646	76.11E	20.32N	
29	CHANDRAPUR	193	79.18E	19.57N	
30	NAGPUR	310	79.07E	21.09N	
31	YAVATMAL	451	78.08E	20.23N	
3	WARDHA	283	78.37E	20.45N	
233	GADCHIROLI	217	80.00°E	20.10°N	
34	WASHIM	546	77.10E	20.14N	
35	GONDIA	300	80.18E	21.28N	

3.2 Statistical methodology

The methodology used in this study is a probability analysis of the rainfall statistic (Table 1) using plotting positions from the initial research and analysis. The data was separated into distinct categories in order to determine seasonal, yearly, and regional variability. Data were categorised by season for seasonal variability, including winter (January, February), summer (March, April, May), monsoon (June, July, August, September), post-monsoon (October, November, December), and annual (12-month mean). Additionally, various statistical metrics for variability analysis are computed, including standard deviation, cumulative variation, skewness, and kurtosis.

Table 2. Formulae for statistical parameters

Description	Symbol	Formula	Explanation
Arithmetic mean	Xavg	$sum(\frac{xi}{n})$	used to calculate average monthly as well as annual rainfall values
Standard Deviation (SD)	Σ	∑ (Xi – Xavg) 2 / (n-1)1/2	It indicates rainfall magnitude; the annual rainfall data is analysed and the variation in distribution over the area is studied
Co-efficient of Variation (CV)	Cv	$100x(\frac{\sigma}{Xavg})$	Coefficient of variation shows the change from the mean values of rainfall.
Co-efficient of Skewness	Cs	(1 / σ 3) x [(N / (N 3N +2)] x ∑ (Xi – Xavg)3	Skewness represents the distribution of data about the mean. It is equal to zero in the case of normal distribution.
Co-efficient of Kurtosis	Ck	Σni(Yi – Ȳ)2 / n	The kurtosis showed a negative value for all the rainfall type which means flatter than normal peak distribution.

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4. Result and Discussion:

4.1 Season wise Mean Rainfall Variability-

The Seasonal Mean Rainfall data is analysed and the variability in distribution over the study region with the average seasonal (summer, Winer, Monsoon, Post monsoon and Annual) values are procured for the period 1901-2015 years.

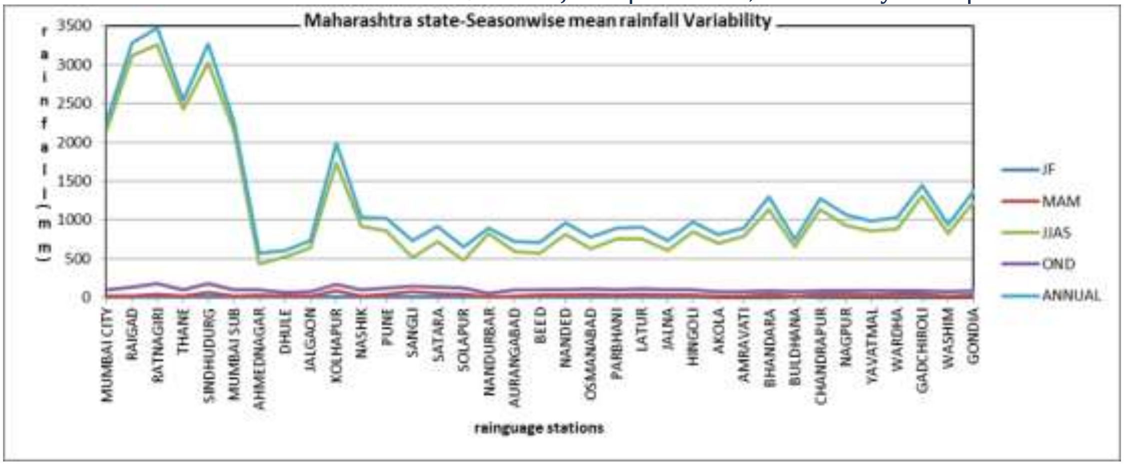

Figure 2. Maharashtra state-season wise mean rainfall

The Line graph (Fig. 2.) shows the mean rainfall over Maharashtra for the period 1901-2015. During this period the highest annual rainfall recorded is 3470.6 mm recorded in Ratnagiri and the minimum annual rainfall was 537.6 mm recorded in Ahmednagar. In winter season highest rainfall occurred in Bhandara (29.1mm) and lowest rainfall occurred in Ratnagiri (0.1mm), In summer season highest rainfall occurred in Kolhapur (90.7) and lowest rainfall occurred in Nandurbar (11.1mm) , In monsoon season highest rainfall occurred in Ratnagiri (3261.5 mm) and lowest rainfall occurred in Ahmednagar (437.6mm), In post monsoon season highest rainfall occurred in Sindhudurg (183.4 mm) and lowest rainfall occurred in Nandurbar (50.2mm).

4.2. Season wise CV rainfall variability-

The Seasonal CV Rainfall data is analysed and the variability in distribution over the study region with the average CV rainfall values (June, July, August, September, JJAS and Annual) are procured for the period 1901-2015 years.

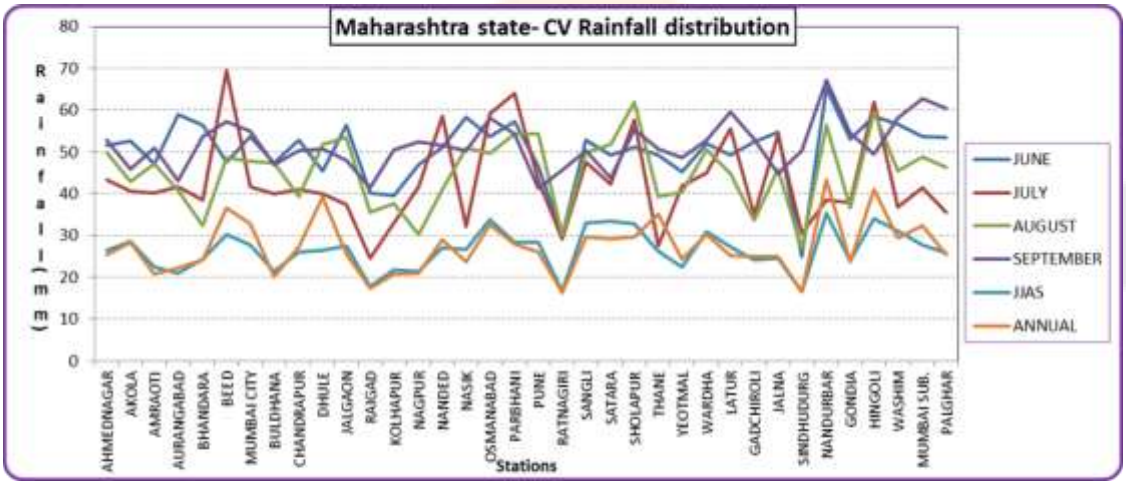

Figure 3. Maharashtra state season wise cv rainfall distribution

The Line graph (Fig. 3) shows the CV (%) over Maharashtra state for 36 districts During this distribution the highest CV recorded in Beed during the month of July (69.4%) and the minimum CV was recorded in Sindhudurg (16.6%) and for annual CV distribution highest value recorded in Nandurbar (43.3%).

4.3.Spatio-Temporal Rainfall Variability

For temporal rainfall variability the average annual rainfall data for 4 meteorological divisions was analysed and its variability in distribution over the study region with the statistical parameter's average annual rainfall data for the period 1901-2015 years.

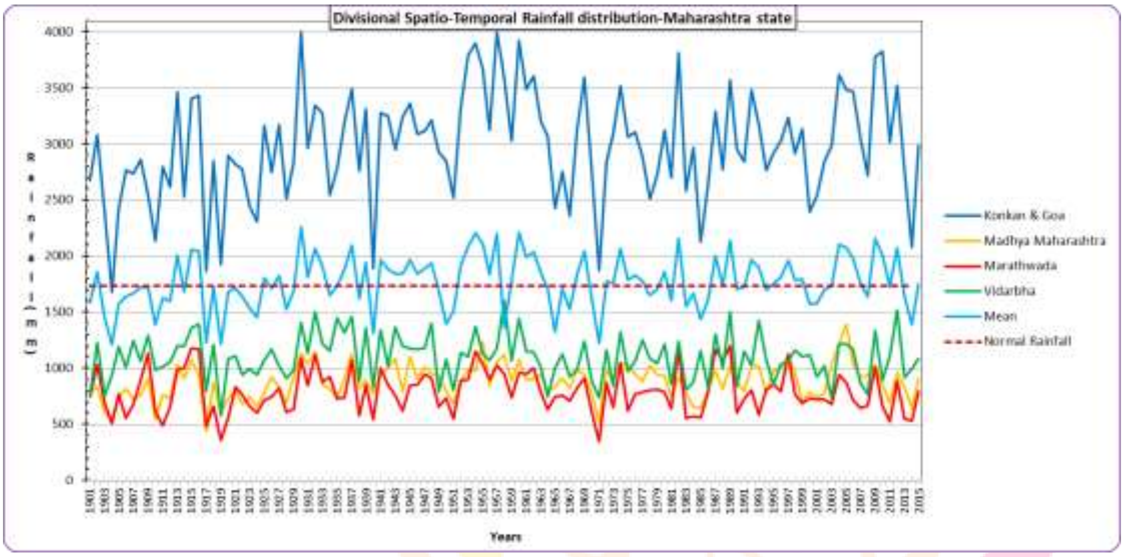

Figure. 4. Spatio-Temporal Variation of Annual Rainfall over the 4 Meteorological Divisions

This line graph shows (Fig.4) Spatio-Temporal Rainfall Variability over the 4 division of Maharashtra state for the period 1901-2015. I.e. Konkan & Goa, Madhya Maharashtra, Marathwada and Vidarbha. During this distribution the highest annual rainfall recorded in Konkan and Goa Division (4002mm) in the year 1958 and lowest annual rainfall (1682.8mm) recorded in the year 1904, the highest annual rainfall recorded in Madhya Maharashtra Division (1395.7mm) in the year 2006 and lowest annual rainfall (438 mm) recorded in the year 1918, the highest annual rainfall recorded in Marathwada Division (1198.1mm) in the year 1990 and lowest annual rainfall (347.1mm) recorded in the year 1972, the highest annual rainfall recorded in Vidarbha Division (1366.2 mm) in the year 1958 and lowest annual rainfall (578.5 mm) recorded in the year 1919; And doted red line shows Normal rainfall (1736.2mm).

Table 3. Statistical Parameters of Annual and Seasonal Rainfall Pattern

STATISTICAL PARAMETERS OF ANNUAL AND SEASONAL RAINFALL PATTERN									
DISTRICT	Winter	Summer	Monsoon	Post Monsoon	Annual	SD	CV	Skewness	Kurtosis
Ahmednagar	1.9	29.9	469.5	103.8	591.2	200.9	25.4	1.3	1.7
Akola	13.9	22.9	701.8	76.3	800.6	333.4	28.4	-0.1	-3.2
Amraoti	16.4	17.9	803.9	76.5	896.7	375.9	20.8	0.2	-4.9
Aurangabad	4.1	23	571.5	94.9	681.5	279.5	22.3	-0.1	1.2
Bhandara	29.1	39.3	1081.3	87.1	1202.7	543.3	24.1	0	-5.8
Beed	4.5	30.5	575.4	104	701.6	264.9	36.5	0.1	-1.5
Mumbai City	2	19.4	2040.8	93.7	2146.1	1052.8	32.7	0.4	1.1
Buldhana	7.6	17	656	75.7	747.9	308.1	20.2	0	-5.1
Chandrapur	20.3	37	1103.8	82.9	1232	543.2	27.3	0	-5.6
Dhule	3.5	15.1	545.1	65.1	623.1	249.2	39.2	1.9	3.7

Jalgaon	5.7	13.2	637.1	70.2	716.2	307.4	25.5	0	-4.8
Raigad	0.4	22.2	3077.8	138.6	3235.8	1533.2	17.4	0.5	0.7
Kolhapur	1.8	90.7	1811.8	162.7	2012.9	828.9	20.7	0.2	0.6
Nagpur	24.6	36.6	948.5	83.3	1062.3	438.6	20.9	0.4	-3.2
Nanded	9.4	33.1	762.7	102.2	884.3	386.1	29	-0.2	-4.2
Nasik	1.7	20.8	963.8	94.9	1071.3	438.4	23.8	0.6	-2.5
Osmanabad	6	37.7	575.7	112.2	720.8	289.2	32.5	0.1	-0.4
Parbhani	8.7	29.8	712	101.3	837.6	357.5	27.9	0	-5.9
Pune	0.7	36.6	892	117.4	1018.2	407.6	26	0.9	0.2
Ratnagiri	0.1	35.3	3322	173.7	3537.6	1597.7	16.4	-0.1	1.3
Sangli	2.5	80.9	454.2	139.1	624.1	224.1	29.7	-1.4	2.4
Satara	1.4	53.5	1279.2	133.8	1452.7	334.9	29.2	0.4	0
Sholapur	4.2	42.4	460.1	125.7	601.7	214.5	29.6	1.6	2.9
Thane	0.5	14.9	2435.2	98.4	2530.3	1196	35.2	0.7	-0.6
Yeotmal	13.2	30.6	812.9	84	913.5	407.3	24.4	-0.5	-2.8
Wardha	20.4	37.5	862.6	88.8	976.4	416.7	30.2	0.5	-2.7
Latur	8	40.4	671.9	109.1	819.6	352.5	25.2	-0.8	0.1
Gadchiroli	17.2	43.2	1321.9	86.4	1452.7	627.7	24.9	0	-5.9
Jalna	5.2	24.7	584.2	93.4	695.6	285.2	24.9	0	-5.7
Sindhudurg	0.4	63.6	2956.2	183.4	3206.2	1471.6	16.5	-0.5	-0.8
Nandurbar	1	11.1	847.2	50.2	923.9	404.4	43.3	0.5	-2.9
Gondia	26.4	33.8	1218	81.7	1342.9	591.3	23.7	0.1	-5.4
Hingoli	9.8	26.7	750.7	93.8	869.1	404.5	41.1	-0.5	-3.1
Washim	14.7	20.7	788.7	79.9	901.7	394.7	29.3	-0.3	-0.4
Mumbai Sub.	2	19.4	2272.2	93.7	2396.7	1052.8	32.4	0.9	2
Palghar			2361.2		2456.9		25.4	0.8	-0.4
Note: SD=Standard Deviation and CV=Coefficient of variation									

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4.4. Monthly Rainfall analysis

For Monthly rainfall analysis Average Mean and CV rainfall for both the Monsoon and Mean Annual rainfall values were used to see the variability over the Maharashtra state. With the help of Arc GIS thematic maps are prepared for Monsoon and Annual rainfall to clearly detect the variability all over the Maharashtra state.

- **Mean Rainfall Variability-**

(a) (b)

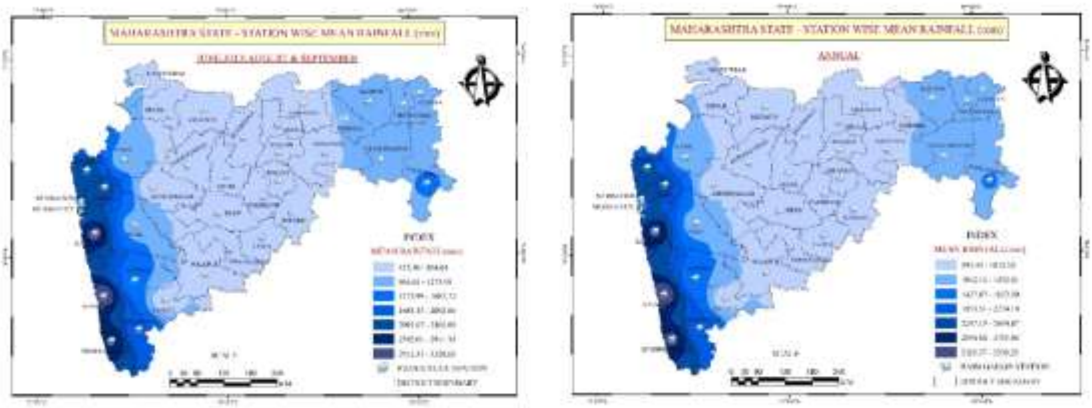

Figure 5. Distribution of Mean Rainfall over the Districts of Maharashtra
Fig. a- Monsoon Season (JJAS), Fig. b- Annual

- **CV Rainfall Variability-**

(a) (b)

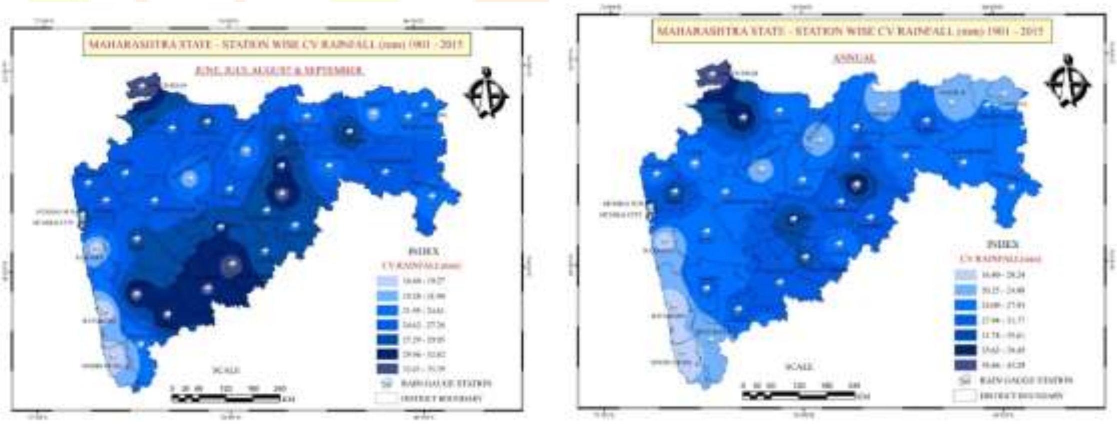

Figure 6. Distribution of Coefficient Of Variation (%) Of Rainfall over the Districts of Maharashtra
Fig. a- Monsoon Season (JJAS), Fig. b- Annual.

As a result, eastern parts of Maharashtra state get some rain whereas western parts receive negligible amount of rain. During the pre- monsoon season, most of the parts of the country along with Maharashtra get rain due to convective activities and thus mean rainfall are almost similar in the districts of Maharashtra. During monsoon season, western parts of Maharashtra get excessive rain due to strong westerlies from Arabian Sea and the presence of offshore trough whereas eastern parts of Maharashtra get rain mostly from the Bay of Bengal branches of monsoon current. The mean rainfall over Madhya Maharashtra is thus less than the western and eastern parts. In post-monsoon season, southern parts of the state get rain from the westerly waves and northeast monsoon to some extent.

5. Conclusion:

Detecting changes in seasonal and annual rainfall variability over Maharashtra State from 1901 to 2015 provides valuable insights into the region's climate patterns and their potential impacts. By analyzing rainfall data in centimetres, researchers can identify long-term trends, variations, and anomalies that may indicate shifts in the state's precipitation patterns. Such analyses allow us to better understand the potential effects of climate change on water resources, agriculture, and ecosystems in Maharashtra.

Detecting changes in rainfall over the state of Maharashtra; the trend study was performed over a much longer time period, from 1901 to 2015. The MK test is performed on a time series. This study demonstrates that there is geographic diversity in the volume and direction of long-term rainfall changes across Maharashtra state. However, no discernible pattern can be found in the trend values for distinct subdivisions. Long-term trend values are insignificant across all sub-divisions. Annual and SW monsoon rainfall statistics reveal a negligible positive trend across the Maharashtra region. The rising tendency over Konkan, Goa, and Madhya Pradesh is attributed to an increase in rainfall during the SW monsoon season, notably around August. The declining tendency in monsoon rainfall over this region is causing a negative trend in rainfall across Vidarbha and Marathwada. The topographical structure is mostly responsible for such a rainfall trend distribution.

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Acknowledgement:

I would like to thank Chhatrapati Shahu Maharaj Research Training and Human Development Institute SARTHI), Pune (Govt. of Maharashtra, India) for financial support under the project CSMNRF-2019, and of course, my supportive, motivating spouse, without whom I would not be able to do this task.