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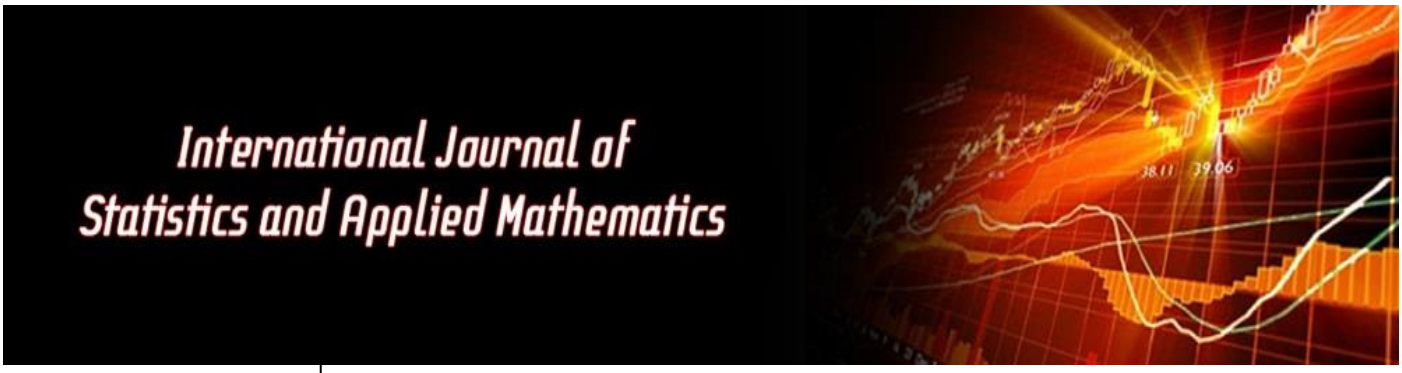

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Statistical analysis of rainfall pattern and trend of Parbhani district, Maharashtra

Serene Toppo, RV Chavan and SV Bharati

Abstract
Rainfall regime is perhaps the most important factor in determining the potential productivity of various agricultural activities. To analyze, the extent of variation in the rainfall pattern in the study area, the short term time series weather data was used for a period of 10 years i.e. from 2013-2023 and the annual rainfall data was obtained from the department of Agrometeorology, College of Agriculture, Vasantrao Naik Matrathwada Krishi Vidyapeeth, Parbhani. The data related to production of crops were collected from Government of Maharashtra statistical database. The statistical descriptive measures namely, mean, standard deviation (SD), Coefficient of variation (CV), Minimum, Maximum, Skewness, Kurtosis have been calculated. Using linear trend, the change in rainfall has been evaluated. It is observed that district receives maximum amount of rainfall that the district receives the maximum amount of rainfall from the southwest monsoon, around 81.61 per cent from June to September, the district receives 17.39 per cent in June and 26.96, 15.33 and 21.93 per cent rainfall in the month of July, August and September, respectively. The rainfall in Parbhani district showed considerable variation from year to year, with both positive and negative deviations from the normal levels with some years experiencing significant deviations from the normal rainfall affecting both surplus and deficit conditions across the prevailing seasons. Monsoonal rainfall is correlated with crop production. The correlation values between crop production and monsoon rainfall give an insight into how dependent each crop is on monsoon rains Pulses like tur, green gram and black gram have higher correlations with monsoon rainfall indicating they are highly sensitive to monsoon variations. Oilseeds like groundnut, sesamum and soybean have relatively low correlations, which may indicate adaptability or the availability of irrigation in growing region. The findings suggest a need for improved rainfall forecasting and adaptive agricultural strategies to mitigate the effects of both years of deficit and years of excessive rainfall. The district experienced periods of excess rainfall and drought-like conditions, leading to an unpredictable agricultural environment.

Keywords: Rainfall, monsoon, trend, regression, correlation

1. Introduction
Agriculture is the mainstay of the population in the rainfed areas. Agriculture sector continues to be highly sensitive to monsoon variability about 65% of India's cropped area is rain-fed, 75% of rainfall is obtained from the southwest monsoon and 25% from the northeast monsoon. Agriculture accounts for 59% of the country's total workforce (FAO, 2016). There is direct influence of global warming on changes in precipitation. The decline in rainfall can be directly associated with the warming influence on the condensation level (Trenberth, 2011) [10]. A report by the Government of India Ministry of Earth Sciences notes that the middle of the twentieth century, India has experienced rise in average temperature, decrease in monsoon, rise in extreme temperature, rainfall, droughts events and an increase in intensity of severe cyclones and other changes in the monsoon system. Indian monsoon has been experiencing extreme rainfall events in several parts of the country, adversities of climate change vary according to region, it has great impact on agricultural productivity and cropping pattern, agriculture largely contingent on monsoon rains also growing population and growing economy imposed a threat to limited resource base as more than half of the 1.3 billion population directly depend on climate sensitive sectors (agriculture, forestry, fisheries etc.). The impact of climate change on Indian monsoon is characterized by seasonal winds and heavy rainfall causing variations in rainfall on agricultural seasons, such as increase in the intensity of rainfall events, frequency of droughts during growth of crops.

Trend is the general movement of a series over an extended period or as the long- term change in the dependent variable over an extended period. The relationship between two variables, such as temperature and time or rainfall and time, determines the trend (Sahu *et al.*, 2018) [8].

The main concern raised by climate change is the climate variations altering the water cycle. Studies on inter- annual and long – term variability of monsoon rainfall have indicated that variation in rainfall for the Indian subcontinent is statistically significant (Thapliyal and Kulshrestha, 1991; Srivasatava *et al.*, 2016) [9]. Changes in regional climate, such as shifts in temperature or rainfall, can significantly disrupt the established agricultural practices and systems. Climate variability is mainly driven by two key factors: rainfall and temperature. Rainfall variability manifests in two forms- its overall quantity and how it is distributed over time. Of these, the distribution of rainfall tends to have a greater impact on crop production than changes in total rainfall. Climate change, particularly in the form of extended dry spells, droughts, or floods during critical crop-growing periods, threatens the livelihoods of farmers. A high degree of correlation also exists between the rainfall and agriculture production (Gadgil, 1996) [1]. These adverse climatic events can force farmers into difficult social and economic situations, such as selling their crops at distress prices, parting with livestock or farming tools, or even migrating to cities in search of better opportunities. Understanding climate variability at the regional level is essential for grasping its direct and indirect effects on cropping patterns and the broader agricultural economy of the region. If the rainfall pattern, farmers face very adverse condition for farming and ultimately production decreases, therefore the study about pattern and trend is needed to understand the impact of rainfall variability on agriculture.

2. Materials and Methods

The present study was collected and compiled from various secondary sources. The data related to rainfall was collected from the Department of Agrometeorology, College of Agriculture, Vasantrao Naik Matrathwada Krishi Vidyapeeth, Parbhani. The data related to production of crops were collected from Government of Maharashtra statistical database. The statistical descriptive measures namely, mean, standard deviation (SD), Coefficient of variation (CV), Minimum, Maximum, Skewness, Kurtosis have been calculated.

2.1 Trend analysis

To determine the trend of rainfall in Parbhani district of Maharashtra State, Time series analysis was used. Trend analysis for selected variables were estimated with the help of linear equation. The linear trend the of linear equation. The linear trend was workout with the help of linear regression equations.

Linear regression equations

$$Y = a + bx$$

Where,

Y= weather data (rainfall/ maximum & minimum temperature)

a = intercept

b= slope

x = year/time

2.2 Pearson Correlation Coefficient (r)

Pearson correlation coefficient (r) is a measure of strength of the association between two variables. Pearson correlation coefficient was used to know the correlation between the monsoon rainfall and crop production. During the analysis, precipitation was taken as an independent variable and crop production as dependent variable to estimate the impact of precipitation on production. For evaluating significance level, t test method was used.

$$r = \frac{n\,(\sum xy) - (\sum x)\,(\sum y)}{\sqrt{[\,n\sum x^2 - (x)^2\,)]\,[\,n\,\sum y^2 - (y)^2\,)]}}$$

Where,

r = Pearson correlation coefficient

n = pairs of observations

x = crop production

y = monsoon rainfall

3. Results and Discussion

3.1 Parbhani district Trend and Pattern of Changes in Rainfall over the Years

Initially various selected descriptive measures namely, mean, standard deviation (SD), Coefficient of variation (CV), Minimum, Maximum, Skewness, Kurtosis were applied to the monthly, seasonal and annual rainfall of the Parbhani district during the period from 2013-2023, as to know the behavior of rainfall. From Table 1, the mean annual rainfall of Parbhani district is 995.62 mm with coefficient of variation of annual rainfall is 32.86 per cent. High degree of variability was observed in annual rainfall series since standard deviation and coefficient of variation (CV) was high. The rainfall variability was more as the average monthly rainfall of coefficient of variation (CV) ranges from 47.5 to 243.8 per cent, which means that the spread of data points in the data series is around the mean. The rainfall variability was understood by CV, i.e. rainfall variability is less if CV is less than 20 per cent, the variability is moderate if CV is 20 to 30 per cent and variability is high if it is more than 30 per cent (Naveena *et al.*, 2020) [5]. The highest average rainfall was reported in July 268.45 mm which ranges to 13.6 to 568.8 mm, while the least average rainfall was observed in January 1.25mm, which ranges to 0 to 9.2 mm. It indicated that the months of January and July were the extreme precipitation months of Parbhani district of Maharashtra during the study period 2013-2023. Based on CV highest value was observed for November (243.86 %) which might be due to irregularities of rainfall during the period and least CV was observed for August (47.59 %) implies that rainfall was consistent. Similar results were found by Pandya *et al.* (2023) [6]. Skewness measures the asymmetry of distribution around the mean. Rainfall during the months January to December except for October and Northeast monsoon which were negatively skewed. The maximum skewness 3.15 was obtained for November month, whereas the October month and northeast monsoon was negatively skewed with -0.06 and -0.28 respectively. Kurtosis provides an idea about the flatness or peakedness of the frequency distribution curve. Lepto Kurtic (>3) values were observed for the periods of April, May, Nov, Dec which indicated that those data comprised of extreme outliers. From Table 2, It is evident that the district receives the maximum amount of rainfall from the southwest monsoon, around 81.61 per cent from June to September, the district receives 17.39 per cent in June and 26.96, 15.33 and 21.93 per cent rainfall in the month of July, August and September, respectively. Rainfall from the southwest monsoon falls between June and

September at rates of 17.39 percent and 21.93 percent, respectively. Also, only the southwest monsoon season brings around 81.61 percent of the yearly rainfall. The annual rainfall and monsoon variability are 33 % and 37% respectively as shown in Table 2.

Table 1: Descriptive statistics of annual rainfall (mm) of Parbhani district from (2013-2023)

Months	Mean	SD	CV	Maximum	Minimum	Skewness	Kurtosis
January	1.25	2.83	225.352	9.2	0	2.69	7.38
February	6.59	9.65	146.38	24.4	0	1.24	-0.21
March	19.93	25.74	129.167	77.1	0	1.41	1.10
April	15.06	27.43	182.08	90.8	0	2.56	6.66
May	16.18	20.92	129.28	69.1	0	1.72	3.69
June	173.11	98.23	56.74	325.8	42	0.27	-0.97
July	268.45	173.93	64.78	568.8	13.6	0.26	-0.99
August	152.64	72.65	47.59	285.1	72.3	0.94	-0.11
September	218.36	132.66	60.74	287.8	8.2	0.18	-0.11
October	105.80	86.02	81.3	248.9	0	-0.06	-1.23
November	14.91	36.36	243.86	123	0	3.15	10.19
December	3.33	7.90	237.46	26.6	0	3.06	9.67
Seasonal							
Southwest monsoon	812.56	299.38	36.84	1450.5	388.3	0.53	1.09
Northeast monsoon	124.04	81.14	65.42	265.1	0	-0.28	-0.25
Premonsoon/ summer	204.35	97.63	47.77	386.3	78.3	0.44	-0.42
Winter	56.15	53.74	95.71	149.9	0	0.87	-0.66
Annual	995.62	327.19	32.86	1717.3	560.2	0.77	1.42

Table 2: Mean rainfall (mm) and coefficient of variation of the district for the monsoon months, southwest monsoon and annual rainfall from 2013-2023

Parbhani	June	July	August	September	Monsoon	Annual
Mean(mm)	173.11	268.45	152.64	218.36	812.56	995.62
	(17.39)	(26.96)	(15.33)	(21.93)	(81.61)	(100)
CV(%)	56.7	64.8	47.6	60.7	36.8	32.9

Figures in the parenthesis indicates the percentage

The rainfall time series in mm for June, July, August and September, as well as for the southwest monsoon season and annual rainfall are shown in Figs. 1 and 2, respectively. For every series, the trend lines are also given. There was no significant increase or decrease in monthly, seasonal or annual rainfall trends exists. While August shows decreasing trend in monthly rainfall, rainfall trends of June, July, September shows non- significant increasing trend. The linear trend line falling on the time series for annual rainfall depicts the increasing and decreasing rainfall trend pattern of the Parbhani district for the period 2013-2023. The value of the coefficient of determination (R^2) for linear equation is at lower magnitude. Similar linear regression analysis for the rainfall variability during the period 1980-2019 in Jagtial district of Telangana state was found in earlier studies. Navatah *et al.* (2021). The results of linear regression trend interpreted that there were both increasing and decreasing trend patterns present in the rainfall data. The computed time series trend analysis of rainfall through linear regression shows a increasing trend with a positive regression slope value of 28.438 indicates a increasing trend through an increase of each time period of 2013-2023. Rainfall of seasonal and annual are on positive trend.

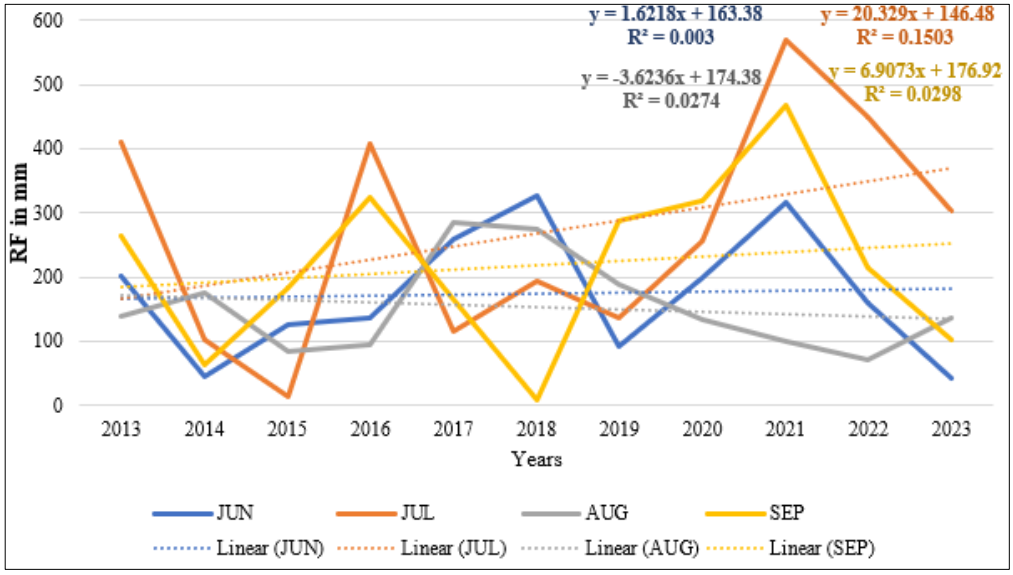

Fig 1: Parbhani district's Monsoon Months Rainfall

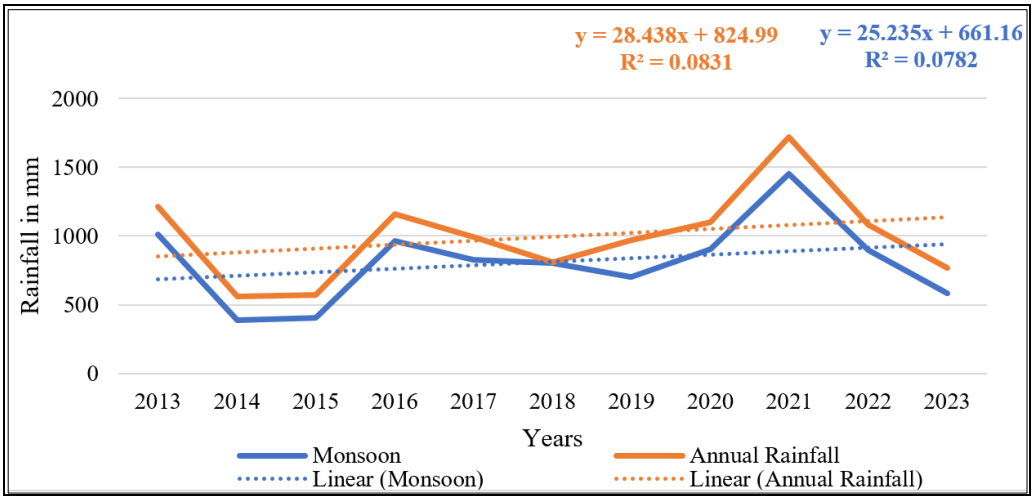

Fig 2: Parbhani District Southwest monsoon and Annuall Rainfall

3.2. Year wise annual rainfall and deviation from the mean in the Parbhani district

During year 2013, the annual rainfall was 1216 mm and the deviation from the mean was 22 per cent, a positive deviation was observed as shown in Table 3. During 2014 annual rainfall decreased to 560 mm from 1216 mm and the deviation from the mean was -44 per cent, it indicated that the annual rainfall in the year 2014 was less than the mean rainfall. Also, in the 2015 decrease in annual rainfall was observed with 574 mm and deviation from the mean was -42 per cent, indicated annual rainfall was less than the mean rainfall. In the year 2016, the annual rainfall was 1159 mm which was much more than the mean rainfall with a positive deviation of 16 per cent. In 2017 no deviation from the mean annual rainfall was observed. In the year 2018, annual rainfall decreased from the previous year 2017 to 812 mm and deviation from the mean annual rainfall was -18 per cent. In the year 2019 there was slight increase in the annual rainfall and its deviation from mean annual rainfall was -3 per cent.

Table 3: Year wise annual rainfall (mm) and deviation from the mean rainfall in Parbhani district

Years	Annual Rainfall (mm)	Deviation from the mean (%)
2013	1216	22
2014	560	-44
2015	574	-42
2016	1159	16
2017	996	0
2018	812	-18
2019	969	-3
2020	1099	10
2021	1719	73
2022	1080	8
2023	768	-23
Mean	995.61	
CV (%)	32.86	

The annual rainfall during 2020, 2021 and 2022 with annual rainfall of 1099 mm, 1719 mm and 1080 mm was observed there was increase in the annual rainfall during the years 2020, 2021 and 2022 from the mean annual rainfall with a positive deviation of 10 per cent, 73 per cent and 8 per cent respectively. In 2023 annual rainfall decreased to 768 mm with a negative deviation of -23 per cent from the mean annual rainfall. Thus, the overall rainfall pattern showed a variation in the annual rainfall from year to year which indicated the rainfall is not uniform over the years. The annual rainfall was highest during 2021 with 1719 mm and lowest annual rainfall was observed during the year 2014 with 560 mm with the negative deviation of - 44 per cent from the mean annual rainfall. Similar results was found by Patil (2014) [7].

3.3 Deviation of annual rainfall over the normal rainfall in the Parbhani district

The change in climatic variables particularly rainfall pattern has a great impact on cropping pattern of the region. From the Table 4, it is very clear that there was no stability in the rainfall pattern. The annual rainfall in the year 2013 was 1216 mm and the deviation over the normal rainfall was 29 per cent and the deviation over the previous period was 43 per cent, it indicated that during 2012 the annual rainfall was more than the normal rainfall but in the year 2013 the rainfall was less than the normal rainfall. During 2014 the deviation over the normal rainfall and deviation over the previous period were -40 per cent and -117 per cent respectively. In year 2015 the deviation over the normal rainfall was -38 per cent and the deviation over the previous period was 2 per cent. It indicated that compared to previous year the annual rainfall increased. During 2016 the deviation from normal rainfall was 23 per cent and the deviation over previous period was 50 per cent indicated that compared to 2015 the rainfall was increased in the year 2016. In the year 2017 annual rainfall decreased from the normal rainfall by 6 per cent also the deviation of rainfall from previous year was -16 per cent indicated that there was decrease in rainfall in the 2017 as compared to its preceding year annual rainfall. Year 2018 shows negative deviation of 13 per cent from the normal rainfall also the deviation over its previous period was -22 per cent indicating there is decrement in annual rainfall in the year 2018 as compared to its previous period. The deviation of annual rainfall over the normal rainfall were positive during the years 2019 (3%), 2020 (17%), and 2021 (83%) also the deviation over their previous year were 16 per cent, 11 per cent and 36 per cent respectively. In the year 2022 the deviation of annual rainfall from the normal rainfall was 15 per cent and showed a negative deviation of 59 per cent indicating there is decrese in rainfall as compared to its previous year. During year 2023 the deviation of rainfall from its normal rainfall was -18 per cent and the deviation compared to previous period year annual rainfall was -40 per cent.

Table 4: Deviation of annual rainfall over the normal rainfall in the Parbhani district

Years	Annual Rainfall	Deviation over the Normal Rainfall (%)	Deviation over the Previous Period (%)
2013	1216.1	29.55	43.41
2014	560.2	-40.32	-117.08
2015	573.8	-38.87	2.37
2016	1159.1	23.48	50.50
2017	995.7	6.07	-16.41
2018	812.1	-13.49	-22.61
2019	968.6	3.19	16.16
2020	1098.7	17.04	11.84
2021	1719.3	83.16	36.10
2022	1080.1	15.06	-59.18
2023	768.1	-18.17	-40.62
(Normal Rainfall:	938.7mm)		

3.4 Rainfall variation in Parbhani district (2013-2023)

Based on the rainfall deviations observed from the normal rainfall in Table 4, frequency tables were constructed. The rainfall deviations were found to be both positive and negative. Based on the magnitude of these deviations, positive and negative deviations were constructed also the number of years under these deviations were also worked out and presented in the Table 5. The table indicated all those years in which rainfall was surplus/ deficit and the extent of surplus/deficit rainfall in percentage for the study area during the period. The extent of deviation of annual rainfall from the normal rainfall in Parbhani district region was estimated. The percentage deviations are grouped according to sign i.e. positive deviation and negative deviation are sub- grouped into six categories, less than 10 per cent, 10-20 per cent,20-30 per cent, 30-40 per cent, 40-50 per cent and more than 50 per cent deviation from mean rainfall. During the year 2021, the positive deviation of 50 per cent and above was found. It indicated that rainfall was surplus during the year, for positive deviation of 40 to 50 per cent and 30 to 40 per cent none of the years were found. In the positive deviation of 20 to 30 percent year 2013 was found. For positive deviation of 10 to 20 per cent two years were found they were 2016 and 2020. For the positive deviation of less than 10 per cent two years were found those years were 2017 and 2022. For the negative deviations, the year 2019 was found less than 10 per cent deviation, year 2018 was found under the deviation of 10 to 20 per cent. In the year 2023 negative deviation of 20 to 30 was found. The negative deviation of 30 to 40 per cent none of the years were found. The highest negative deviation of above 50 percent the year was 2014 and 2015.

Table 5: Rainfall variations in Parbhani district (2013-2023)

Percent deviation of rainfall from normal rainfall	Annual Rainfall (%)	South-west Monsoon Rainfall (%)	Post- Monsoon Rainfall (%)
Positive deviations			
>50 %	2021	2021	
40-50 %			2016, 2017, 2021
30-40%		2013	2013, 2022
20-30%	2013	2016	
10-20%	2016,2020	2020, 2022	
<10 %	2017,2022	2017, 2018	2020, 2023
Negative deviations			
<10%	2019	2019	
10-20%	2018		
20-30%	2023	2023	
30-40%			
40-50%	2014,2015	2014,2015	
>50%			2014, 2015, 2018, 2019

The extent of deviation of south-west monsoon rainfall from the normal monsoon rainfall was estimated. During the year 2021, the positive deviation of above 50 per cent was found. It indicates that the monsoon rainfall was surplus during the years. For positive deviation of 40 -50 per cent none of the years were found. For positive deviation of 30-40 per cent year 2013 was found. In the positive deviation of 20 to 30 per cent year 2016 was found. For the positive deviation of 10-20 per cent two years were found they were 2020 and 2022, for the positive deviation of less than 10 per cent two years was found those years were 2017 and 2018. For negative deviation the year 2019 was found to be less than 10 per cent, year 2023 was found under the negative deviation of 20-30 per cent. The negative deviation of 30-40 per cent none of the years were found. The highest negative deviation of above 50 per cent deviation from the normal monsoon rainfall was found to be 2014 and 2015. The extent of deviation of post-monsoon rainfall from the normal post -monsoon rainfall was estimated. Post - monsoon rainfall positive deviation years were 2016, 2017, 2021 which lies between positive deviation of 40-50 per cent. For 30-40 per cent deviation years found to be 2013 and 2022.For less than 10 per cent deviation years were found to be 2020 and 2023. For the negative deviation under less than 10 per cent, 20-30 per cent, 30-40 per cent, 40-50 per cent no years were found. Negative deviation years 2014, 2015, 2018, 2019 found to be highest negative deviations of above 50 per cent from the deviation of rainfall from the normal rainfall.

3.5 Dry and Wet years during period (2013-2023) in Parbhani district

Based on the different frequencies found for the deviation from mean annual rainfall the dry and wet years were classified and are presented in the Table 6. Those years for

which the deviation of the annual rainfall from the normal rainfall was negative were classified as dry years and those years for which the deviation was positive were classified as wet years. The driest years found during the study period were 2014 (560.2 mm), 2015 (573.8 mm), 2018 (812.1 mm), 2019 (968.6 mm), 2023 (768.1mm) in which the deviation from the mean were negative. The relatively wet years found during the study period were 2013 (1216.1 mm), 2016 (1159.1 mm), 2017 (995.7 mm), 2020 (1098.7 mm), 2021 (1719.3 mm), 2022 (1080. mm).

Table 6: Dry and Wet years during period (2013 – 2023) in Parbhani district

Sr. no	Dry Years	Rainfall (mm)	Wet Years	Rainfall (mm)
1	2014	560.2	2013	1216.1
2	2015	573.8	2016	1159.1
3	2018	812.1	2017	995.7
4	2019	968.6	2020	1098.7
5	2023	768.1	2021	1719.3
6			2022	1080.1

3.6 Correlation between agriculture crop production and monsoon rainfall

In order to find relationship between the crop production and monsoon rainfall, the coefficient of correlation method was used. The analysis shows positive correlation of monsoon rainfall and all crops across the study years. The monsoon seasonal rainfall covers the period of June to September as these are sowing and growing period of the region. Monsoonal rainfall is correlated with crop production. The correlation values between crop production and monsoon rainfall give an insight into how dependent each crop is on monsoon rains. Rainfall influence more on cash crops i.e. cotton and sugarcane followed by pulses, oilseeds and cereals as shown in Table 7.

Table 7: Correlation between agriculture crop production and monsoon rainfall

Agriculture crops	Monsoon Rainfall
Rice	0.2
Jowar	0.01
Bajra	0.1
Maize	0.4
Tur	0.8
Green gram	0.7
Black gram	0.6
Groundnut	0.1
Sesamum	0.2
Sunflower	0.4
Soybean	0.2
Cotton	0.6
Sugarcane	0.7

Monsoonal rainfall affects total rice production of the district with positive correlation (R^2 = 0.2).Tur crop shows highest positive correlation (R^2 = 0.8) with total monsoonal rainfall followed by green gram (R^2 = 0.7), sugarcane (R^2 = 0.7), cotton (R^2 = 0.6), black gram (R^2 = 0.6), moderate positive correlation is shown by maize (R^2 = 0.4) and sunflower (R^2 = 0.4) least positive correlation is shown by sesamum (R^2 = 0.2), rice (R^2 = 0.2), soybean (R^2 = 0.2), bajra (R^2 = 0.1) and jowar (R^2 = 0.01). Low correlation (0.0 to 0.2): rice (0.2), jowar (0.01), bajra (0.1), groundnut (0.1), sesamum (0.2), soybean (0.2). These crops show low correlation with monsoon rainfall. It suggests that their production is less dependent on rainfall, possibly due to factors like irrigation or drought tolerance. Moderate correlation (0.3 to 0.6): maize (0.4), sunflower (0.4), black gram (0.6), cotton (0.6). These crops are moderately dependent on rainfall. While rainfall plays an important role in their production, other factors like soil quality, temperature and farming techniques could influence yields. High correlation (0.7 and above): tur (0.8), green gram (0.7), sugarcane (0.7). These crops are highly dependent on monsoon rainfall. Variations in rainfall can greatly affect their production. Insufficient or erratic rainfall might lead to reduced yields. The fluctuation in rainfall over this period would have direct consequences on agricultural activities, particularly in rain-fed areas. Years with lower rainfall (2014, 2023) would likely correspond with lower crop yields and productivity, while the peak rainfall year (2020) might have led to increased agricultural output.

4. Conclusion

The analysis resulted in more variation in the months of July and September rainfall, considered the most suitable time for farming in Parbhani district. It may be developed such varieties which can withstand late onset of monsoon. According to district four monsoon month, monsoon season and annual rainfall statistics, the variation of rainfall is most recorded in the month of July and the variation is slightly less in the month of June and August. Rainfall levels varied significantly from year to year, with the highest recorded in 2021 (1719 mm) and the lowest in 2014 (560 mm). This indicates a lack of uniformity in rainfall distribution. The data shows both positive and negative deviations from the mean annual rainfall (995.6 mm). Positive deviations were observed in years like 2013, 2016, 2020, 2021, and 2022, while negative deviations occurred in 2014, 2015, 2018, 2019, and 2023. Significant increases in annual rainfall occurred in 2020, 2021, and 2022, with deviations of 10 per cent, 73 per cent, and 8 per cent respectively. Decreases were notable in 2014 and 2015 with deviations of -44 per cent and -42 per cent, respectively, and in 2023 with -23 per cent.The year 2021 was an anomaly with a substantial positive deviation (73 per cent) from the mean, whereas 2014 had a substantial negative deviation (-44 per cent).Years such as 2017 and 2019 showed deviations close to zero, suggesting a more stable rainfall pattern during those years compared to others. Overall, the data reflects considerable fluctuation in annual rainfall, indicating that rainfall in the study area is highly variable and does not follow a uniform pattern. The observed rainfall pattern highlights periods of both drought and excess, which would have had a direct impact on agriculture and water resource management. The findings suggest a need for improved rainfall forecasting and adaptive agricultural strategies to mitigate the effects of both drought years (like 2014 and 2023) and years of excessive rainfall (such as 2020). Going forward, it would be useful to examine how these rainfall trends correlate with agricultural production. Pulses like tur, green gram and black gram have higher correlations with monsoon rainfall indicating they are highly sensitive to monsoon variations. Oilseeds like groundnut, sesamum and soybean have relatively low correlations, which may indicate adaptability or the availability of irrigation in growing region. The rainfall in Parbhani district showed considerable variation from year to year, with both positive and negative deviations from the normal levels with some years experiencing significant deviations from the normal rainfall affecting both surplus and deficit conditions across the prevailing seasons. In the regions with more pronounced climate change, crops with

a short duration growing season should be chosen to withstand lack or excess of precipitation. The correlation analysis for crop production and monsoon rainfall reveals that crops with a high correlation to monsoon rainfall are more vulnerable to variations in the monsoon, while those with lower correlations may be more resilient or supported by additional agricultural practices such as irrigation.

5. Future Scope

The district experienced periods of excess rainfall and drought-like conditions, leading to an unpredictable agricultural environment. Adaptation and mitigation strategies are required to deal with changing rainfall patterns. Adaptive strategies, such as improved water storage systems and drought- resistant crops, might be necessary to mitigate the adverse effects of the climate change. Efforts to stabilize and to enhance rainfall through better irrigation infrastructure and water management practices could be crucial for sustaining agricultural production in the district.

6. Conflict of Interest: Authors have declared that no competing interests exist.

7. Authors contribution: Authors contribution are in data analysis, data collection, framing objectives, selecting methodologies, etc.

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