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Long-term variability and trend of rainfall for Bastar Plateau region of Chhattisgarh

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Abstract

Climate change is a natural phenomenon but the rate at which it is changing is alarming and it is mainly due to anthropogenic causes. Agriculture of Chhattisgarh is mainly dependent on rainfall and its distribution. Therefore, the present study has been carried out to analyse the variability and trend of rainfall and rainy days using daily actual rainfall data from 1989 to 2019 which was collected from the Department of Agrometeorology, IGKV, Raipur. Variability of rainfall and rainy days was statistically analysed and trend analysis was worked out through Mann-Kendall test. Highest variability in annual and south-west monsoon rainfall was found in Bijapur district and for north-east monsoon variability was highest for Sukma district. The number of rainy days was found stable in Bastar district. Annual rainfall and south-west monsoon rainfall showed significant increasing trend for Bastar and Bijapur districts. While Bijapur and Dantewada districts reported significant increasing trend for annual rainy days and south-west monsoon rainy days.

Keywords: Rainfall, rainy days, trend analysis, Mann-Kendall test, bastar plateau

Introduction

Rainfall is essential to Indian agriculture as information of occurrence and distribution of rainfall are essential for crop planning, cropping pattern and management of irrigation and reservoir operations. The probability of reduction in productivity increases with the erratic behaviour of rainfall in terms of frequency, intensity and distribution (Apata, 2010) [1]. Designing of water harvesting structures, planning of sowing, and other agricultural operations can all be benefitted from knowing the yearly, seasonal, and decadal rainfall behaviour? In rainfed regions, timely rainfall during the first months of summer is crucial for effective crop growth (Rehman *et al.*, 2009) [8].

Chhattisgarh extends from 80.15'E to 84.24'E longitude and 17.46'N to 24.50'N latitude with an area of approximately 13.5 million hectares. The climate of Chhattisgarh is described as a dry sub-humid with an average annual rainfall of roughly 1188 mm, which is primarily contributed by the south-west monsoon of June-September receiving nearly 89 percent rainfall. (Bhelawe *et al.* 2014) [8].

The distribution of the rainfall is a significant factor. Based on the fact that a location's capacity to support agriculture cannot be determined only by its annual or seasonal rainfall. The three primary characteristics of rainfall-amount, frequency, and intensity-should be the focus of attention for agricultural purposes. These are: how much rain falls, when it falls, and what the intensity of the rainfall events is. These characteristics' values vary from location to location, day to day, month to month, season to season, and year to year. These three key characteristics must be precisely understood in order to use water resources effectively. Therefore, knowledge of the trend and variability of rainfall is essential to work out the supplemental water requirement of different crops during their critical growth periods. Thus, the objective of this study is to investigate rainfall variability and trend of rainfall and rainy days at Bastar Plateau region of Chhattisgarh.

Materials and Methods

Study area and data used

Bastar division having latitudes of 17° 46' N and 20°34' N latitudes and 80°15' E and 82°15' E longitudes covers six districts, viz., Sukma, Bijapur, Dantewada, Narayanpur, Bastar and Kondagaon. Jagdalpur, the headquarters of Bastar district is representative of Bastar division. The division covers an area of 39114 sq km. In this study, only 5 districts i.e., Bastar, Bijapur, Dantewada, Narayanpur and Sukma are considered. To examine the variability and trend of

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rainfall, long term daily actual rainfall for over a period of 1989-2019 (31 years) were collected from the Department of Agrometeorology, IGKV, Raipur. The geographical information about the stations is presented in Table 1.

Table 1: Geographical location of districts under study

Sl. No.	Districts	Stations	Latitude	Longitude
1.	Bastar	Jagdapur	19°05' N	82°02' E
2.	Bijapur	Bijapur	18°50' N	80°50' E
3.	Dantewada	Dantewada	18°53' N	81°21' E
4.	Narayanpur	Narayanpur	20°17' N	81°07' E
5.	Sukma	Sukma	18°40' N	81°67' E

Methodology

Statistical analysis

$$Mean = \frac{\sum Xi}{n}$$

Where, i = 1, 2, 3, 4, n

$$Standard\ Deviation = \frac{\sum(X - \bar{X})^2}{n - 1}$$

Where, X = Rainfall frequency

\bar{X} = Mean rainfall

n = Number of years

$$Coefficient\ of\ variation\ (\%) = (Standard\ deviation)/Mean \times 100$$

2.2.2 Mann-Kendall's Test

This method tests whether there is a trend in the time series data. It is a non-parametric test. The n time series values (X1, X2, X3, Xn) are replaced by their relative ranks (R1, R2, R3, Rn) (starting at 1 for the lowest up to n).

The test statistic S is:

$$S = \sum_{i=1}^{n-1} \left[\sum_{j=i+1}^n sgn(Ri - Rj) \right]$$

Where,

Sign(x) = 1 for x > 0

Sign(x) = 0 for x = 0 sign(x) = -1 for x < 0

If the null hypothesis Ho is true, then S is approximately normally distributed with:

$$\mu = 0$$

$$\sigma = n(n - 1)(2n + 5) / 18$$

The z-statistic is therefore (critical test statistic values for various significance levels can be obtained from normal probability tables):

$$z = |S| / \sigma 0.5$$

A positive value of S indicates that there is an increasing trend and vice versa.

Results and discussions

The annual rainfall, rainy days and its standard deviation (SD), coefficient of variation (CV) of five districts of Bastar plateau region of Chhattisgarh were worked and presented in table 2 and 3.

Annual and seasonal variation in rainfall in different districts of Bastar plateau region of Chhattisgarh

Table 2 revealed that the highest average annual rainfall 1547 mm was observed in Sukma district followed by Bastar (1475mm) and Narayanpur (1429 mm) respectively while lowest value 1326 mm was recorded for Dantewada district. Highest value of SD and CV of the mean annual rainfall was observed in Bijapur district 403.84 mm and 28.91% respectively while lowest SD 243.37 mm and CV 18.35% was noticed in Dantewada district.

The average south-west monsoon rainfall was found highest 1328 mm at Sukma district (1328 mm) followed by Narayanpur (1257 mm) and Bijapur districts (1240 mm) while lowest rainfall amount during south-west monsoon 1037 mm was observed in Dantewada district. The SD and CV of the average south-west monsoon rainfall was reported highest 417.33 mm and 33.66% at Bijapur district whereas lowest value of SD 294.82 mm and CV 24.80% was observed in Bastar district.

The average north-east monsoon rainfall was observed highest for Bastar district 119 mm followed by Sukma 107 mm and Bijapur 89 mm, respectively while lowest value of rainfall 73mm was found in Dantewada. The highest SD and CV 100.37 mm and 93.39% for the north-east monsoon rainfall was observed in Sukma district while lowest SD 55.64 mm was noticed in Dantewada district and lowest CV 70.28% was found in Bijapur district. This shows that north-east monsoon rainfall is stable in Bijapur than other districts.

Sukma districts recorded more rainfall during Annual and South-west monsoon as compared to other districts while highest rainfall during North-east season was recorded in Bastar district. While Bijapur showed more variation in annual and south-west monsoon season rainfall. Sukma district reported more variation in north-east season rainfall as compared to other districts.

Table 2: Statistical summary of annual and seasonal rainfall of 5 districts of Bastar plateau region from 1989-2019

S. No.	Districts	Annual rainfall			Seasonal rainfall					
		Mean	SD	CV	Mean	SW	CV	Mean	NE	CV
		(mm)		(%)	(mm)	SD	(%)	(mm)	SD	(%)
1.	Bastar	1475	351.5	23.84	1188	294.82	24.80	119	93.46	78.27
2.	Bijapur	1397	403.84	28.91	1240	417.33	33.66	89	62.22	70.28
3.	Dantewada	1326	243.27	18.35	1037	314.65	30.35	73	55.64	76.00
4.	Narayanpur	1429	332.65	23.27	1257	335.90	26.72	75	65.07	86.19
5.	Sukma	1547	394.51	25.5	1328	415.23	31.26	107	100.37	93.39

Annual and seasonal variation in rainy days in different districts of Bastar plateau region of Chhattisgarh

Table 3 revealed that the highest average annual rainy days 87 days was found in Dantewada district followed by Bastar (75 days) and Bijapur (69 days) districts respectively while lowest annual rainy days 65 days was observed in Sukma district. Highest SD of average annual rainy days was observed in Dantewada district 18.38 days and lowest value of SD 11.92 days was found in Bijapur district. Highest value of CV of average annual rainy days was observed in Narayanpur (24.59%) while lowest value of CV was found at Bastar district (16.32%).

The rainy days during south-west monsoon was found highest 63 days at Dantewada district followed by Bijapur and Narayanpur (58 days) while lowest rainy days 55 days was recorded in Sukma district. Highest SD and CV was observed in Narayanpur district 15.96 days and 27.5% respectively while lowest SD 7.75 days and CV 13.8% was noticed in Bastar district.

The rainy days during north-east monsoon was found highest 6 days at Bastar, Bijapur and Dantewada districts while lowest rainy days 5 days was recorded in Narayanpur and Sukma districts. Highest SD and CV was observed in Sukma district 4.41 days and 89.39% respectively while lowest SD 3.62 days and CV 57.9% was noticed in Bijapur district.

The rainy days during kharif season was found highest 68 days in Dantewada district followed by Narayanpur (63 days) and Bijapur (62 days) while lowest rainy days 59 days was observed in Sukma district. Highest SD and CV was reported in Narayanpur district 18.94 days and 30.25% respectively while lowest SD (9.33 days) and CV (15.38%) was noticed in Bastar district.

The rainy days during *rabi* season was found highest 11 days in Dantewada district followed by Bastar (5 days) and Bijapur (4 days) while lowest rainy days 2 days was observed in Narayanpur district. Highest SD 10.99 days was observed in Dantewada district while lowest value of SD 3.61 days was reported in Bastar district and highest CV was reported in Sukma district 203.83% while lowest CV 69.89% was observed in Bastar district.

Cropping pattern of Chhattisgarh is primarily rainfed, hence food grain production depends on the monsoon season. Rainfall analysis is important in view of crop planning for any region. Study of its variability and trend analysis can give more information for crop planning for rainfed region. The knowledge of total rainfall and its distribution throughout the year is extremely useful and important for better planning of cropping pattern developing, irrigation and drainage plans for an area. The coefficient of variation shows the variation in rainfall in an area. High CV values shows chances of instability in an area of the region while low CV value

indicates the rainfall was stable.

Similar work was done by Khavse and Chaudhary (2019) [6], they analysed the rainfall and drought characteristics for crop planning in Plain zone of Chhattisgarh by using daily rainfall data of 55 years (1960-2015) of Raipur district of Chhattisgarh. The average annual rainfall at Raipur was 1158 mm with 29 per cent coefficient of variation indicating thereby that the rainfall was not much stable over the years. July was the highest rainfall recipient month (616 mm) followed by August (519 mm) during the monsoon period.

Trend analysis of annual and seasonal rainfall for different districts of Bastar plateau region of Chhattisgarh

The daily rainfall data of 31 years (1989-2019) were calculated on annual and seasonal basis and trend analysis was carried out through non-parametric Mann-Kendall's test. Table 4 revealed that out of 5 districts, only Bijapur district showed highly significant increasing trend in annual rainfall at 1% level of significance. While two other districts i.e., Bastar and Sukma reported significantly increasing trend at 5% level of significance. Whereas, non-significant increasing trend of annual rainfall were observed in two districts named Dantewada and Narayanpur respectively. During south-west monsoon season, rainfall showed highly significant increasing trend in Bijapur and Bastar district at 1% level of significance. While, 2 districts i.e., Narayanpur and Sukma were reported non-significant increasing trend. Whereas, non-significant decreasing trend in south-west monsoon rainfall was observed in Dantewada district. Two districts named Dantewada and Sukma showed non-significant increasing trend of rainfall during north-east monsoon while non-significant decreasing trend of north-east monsoon rainfall was found in 3 districts i.e., Bastar, Bijapur and Narayanpur.

In annual rainy days, Dantewada showed significant increasing trend at 5% level of significance while Bijapur district reported significant increasing trend at 10% level of significance. Whereas, 3 districts namely Bastar, Narayanpur and Sukma observed non-significant increasing trend in annual rainy days. Out of 5 districts, 3 districts i.e., Bastar, Narayanpur and Sukma districts showed non-significant increasing trend in rainy days during south-west monsoon season. While, highly significant increasing trend was observed in Dantewada district at 1% level of significance. Significant increasing trend was noticed in Bijapur district at 5% level of significance in rainy days during south-west monsoon season. During north-east monsoon season, rainy days showed non-significant increasing trend in 4 districts i.e., Bijapur, Dantewada, Narayanpur and Sukma. While non-significant decreasing trend was noticed in only Bastar district.

Table 3: Statistical summary of annual, season rainy days of 5 districts of Bastar plateau region from 1989-2019

Rainy Days																
S. No.	Districts	Annual			SW			NE			Kharif			Rabi		
		Mean (mm)	SD	CV (%)	Mean (mm)	SD	CV (%)	Mean (mm)	SD	CV (%)	Mean (mm)	SD	CV (%)	Mean (mm)	SD	CV (%)
1.	Bastar	75	12.18	16.32	56	7.75	13.85	6	4.09	64.75	61	9.33	15.38	5	3.61	69.89
2.	Bijapur	69	11.92	17.35	58	13.09	22.64	6	3.62	57.9	62	13.28	21.33	4	3.84	101.92
3.	Dantewada	87	18.38	21.05	63	11.67	18.54	6	4.28	67.77	68	12.42	18.39	11	10.99	102.35
4.	Narayanpur	68	16.73	24.59	58	15.96	27.56	5	4.11	77.66	63	18.94	30.25	2	4.08	172.43
5.	Sukma	65	12.08	18.52	55	13.15	23.91	5	4.41	89.39	59	14.20	24.00	3	5.50	203.83

Table 4: Trend analysis of annual and seasonal rainfall for 5 districts of Bastar plateau region

Sl. No.	Districts	Annual	South-West	North-East
			Monsoon	Monsoon
1	Bastar	Inc (S**)	Inc (S***)	Dec (NS)
2	Bijapur	Inc (S***)	Inc (S***)	Dec (NS)
3	Dantewada	Inc (NS)	Dec (NS)	Inc (NS)
4	Narayanpur	Inc (NS)	(NS)Inc	(NS)Inc
5	Sukma	Inc (S**)	Inc (NS)	Inc(NS)

Note: *** Significant at 1 % level, ** Significant at 5 % level, * Significant at 10 % level, NS- Non significant

Table 5: Trend analysis of annual and seasonal rainy days for 5 districts of Bastar plateau region

Sl. No.	Districts	Annual	South-West	North-East
			Monsoon	Monsoon
1	Bastar	Inc (S**)	Inc (S***)	Dec (NS)
2	Bijapur	Inc(S***)	Inc (S***)	Dec (NS)
3	Dantewada	Inc (NS)	Dec (NS)	Inc (NS)
4	Narayanpur	Inc (NS)	(NS) Inc	(NS)Inc
5	Sukma	Inc (S**)	Inc (NS)	Inc (NS)

Note: *** Significant at 1 % level, ** Significant at 5 % level, * Significant at 10 % level, NS- Non significant

Conclusions

Rainfall during annual and south-west monsoon is increased in Bastar and Bijapur districts and its distribution are found good in Bijapur and Dantewada districts due to increasing of rainy days in those districts. But Bijapur district reported highest variability in amount of rainfall during south-west monsoon and annual rainfall.

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