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Statistical Analysis of Rainfall Pattern and Trend of Chhattisgarh State, India

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

To analyze, the present rainfall status and trend, the long term weather data (1980-2020) viz., gridded annual rainfall data was analysed which was obtained from the department of Agrometeorology, Indira Gandhi Krishi Vishwavidyalaya Raipur, Using linear trend, the long-term change in rainfall has been evaluated. It is obsered that the state receives the maximum amount of rainfall from the southwest monsoon, around 87 percent from June to September, the state receives 15 percent in June and the state receives 29,26 and 16 percent rainfall in the Month of July, August and September, respectively. Long term weather data of state rainfall, it is seen that rainfall in June and September is less consistent since the coefficient of variation is around 33 and 30 percent, respectively; we would conclude that rainfall in June has more variability than in monsoon months, SW monsoon and annual rainfall. Average Monsoon and Annual rainfall variability are less than monsoon months. District-wise minimum rainfall variability of June, July, August, and September is around 37 percent (Kanker) and 22 percent (Jashpur). Kabirdham district has a 25 percent variability in August and September. District Kanker and Raigarh varied around 14 percent for monsoon and annual rainfall. As the linear regression in southwest monsoon and

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annual rainfall in the state of Chhattisgarh is increasing in order, but from 1980 to 2020 it shows more fluctuation in trend line, then if a system is developed for agrometeorology station at cluster level or block level and for forecasting, it will be able to account for these changes. From this, farmers will receive timely information about the monsoon and rainfall, allowing them to conduct agricultural activities at the appropriate time.

Keywords: Rainfall; monsoon; trend; regression.

1. INTRODUCTION

According to the sixth assessment report of the Intergovernmental Panel on Climate Change (IPCC), "Heatwaves and humid heat stress will be more intense and frequent during the 21st century. In case of monsoon, both annual and summer monsoon precipitation will increase during the 21st century, with enhanced inter annual variability" [1]. Due to global warming, rainfall quantity, type, and timing are altering or are expected to alter due to increased evaporation, particularly in the tropics [2]. The Climate change is not a new phenomenon in the world. The rise in temperature of the earth surface and in atmosphere, rainfall variability, declining ground water, soil erosion, heavy winds, floods, drought, increasing sea level due to ice melting, hail storm, fog, cyclone, wind speed, earthquake and landslide etc., are all clear evidence of the phenomenon of climate change [3]. 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 [4].

Rainfall quantity, form and timing are changing or are expected to change due to global warming because of increased evaporation, especially in the tropics. This will have a significant influence on the agricultural and non-agricultural industries. Climate instability has been leading to decline in agriculture production, which has a negative effect on health of human, the livelihoods & food security. The rural people are mostly susceptible to the climate changes and variability due to their dependence on agriculture for the food and livelihood. For example, people in the Himalayan area of Hindu Kush, which includes South Asian countries viz., some parts of India, Bangladesh and Nepal are mostly more vulnerable to the climate change because of high dependence on agriculture for livelihood, poor infrastructure, low productivity, physical isolation and limited access to global markets [6]. In crop production, rainfall is a key factor. Crop or food production is sensitive to the climate changes viz., monsoon (South-West monsoon) rainfall fluctuations and changes in temperature within a season. Out of 5.6 million hectares gross cropped area, 4.7 million hectares area is under cultivation in south west monsoon (rainy season). In kharif, about 3.6 million hectares of area is covered by rice. Just about 36% of the land is irrigated and rest is under rain-fed situation. If the pattern of changes, farmers face very adverse condition for farming and ultimately production decreases. therefore a intenstive study about pattern and trend is needed to understand the pattern and to stable farming practices.

2. MATERIALS ANS METHODS

Department of Agrometeorology, Indira Gandhi Krishi Vishwavidyalaya, Raipur, has provided the observatory data of daily and monthly rainfall data for the period 1980-2020. These daily and monthly observations were processed and calculated its annual average. Trend as 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 [6]. Temperature and precipitation trend significance is determined using statistical techniques such as regression analysis and coefficient of determination R2.The mean and coefficient of variation (CV) have been calculated to analyze rainfall data.

2.1 Trend Analysis

Trend analysis for selected variables were estimated with the help of linear equation. The linear trend was workout with the help of linear regression equations.

2.2 Linear Regression Equations

$$Y = a + bx$$

Where,

Y = weather data (rainfall/ maximum & minimum temperature)
a = intercept
b = slope
x = year/time

3. RESULTS AND DISCUSSION

3.1 State Trend and Pattern of Changes in Rainfall over the Years

Table 1 displays the state's mean rainfall in millimetres (MM) and coefficient of variation (CV) for the annual, southwest (SW) monsoon season and monsoon months from 1980 to 2020. It is evident that the state receives the maximum amount of rainfall from the southwest monsoon, around 87 percent from June to September, the state receives 15 percent in June and the state receives 29,26 and 16 percent rainfall in the Month of July, August and September, respectively.

Rainfall from the south west monsoon falls between June and September at rates of 15 percent and 16 percent, respectively. Also, only the southwest monsoon season brings around 88 percent of the yearly rainfall. The annual rainfall and monsoon variability are quite low around 10 percent.

Uneven distribution of rainfall decreases in the availability of irrigation and domestic water and extreme weather events are the probable consequences of the global increase in average surface temperature. It has been illustrated in terms of frequent events viz., drought, flood, rise in sea levels, storms and melting of glaciers. The amount of rainfall and it is distribution has become highly uncertain. These changes are also appearing on the horizon and causing serious threat to food security of the nation [5].

The annual mean of total monthly rainfall observed an decreasing trend having an decrease of 0.188 mm per year. This indicates at Labandi station annual TMRF has decreased by 8.08 mms during the last 43 years [7]. Data collected over 40 years of state rainfall, it is seen that rainfall in June and September is less consistent since the coefficient of variation is around 33 and 30 percent, respectively; we would conclude that rainfall in June has more variability than in monsoon months, SW monsoon and annual rainfall. Average Monsoon and Annual rainfall variability are less than monsoon months. The annual and monsoon precipitation index exhibited a significance decreasing trend at all stations except in districts Bilaspur and Dantewada during the study period of 1901-2002. They also observed highest percentage of variability in winter precipitation (88.75 %) and minimum percentage of variability in annual series (14.01 %) over the given periods [8].

The rainfall time series in mm for June, July, August, and September, as well as for the southwest monsoon season and annually, are shown in Figs. 1 and 2, respectively. For every series, the trend lines are also visible. There was no significant increase or decrease in monthly, seasonal, or annual rainfall trends exists.The impact of variability and trends in rainfall on production and productivity of different crops at two rain shadow districts viz. Rajnandgaon and Kawardha. They used rainfall data of 1963-2015 and crop data of 2000-2014 collected from department of agrometeorology and agriculture studies. Results revealed that the Rice and gram are the predominant crops and they show an increasing trend of productivity in both the districts [4].

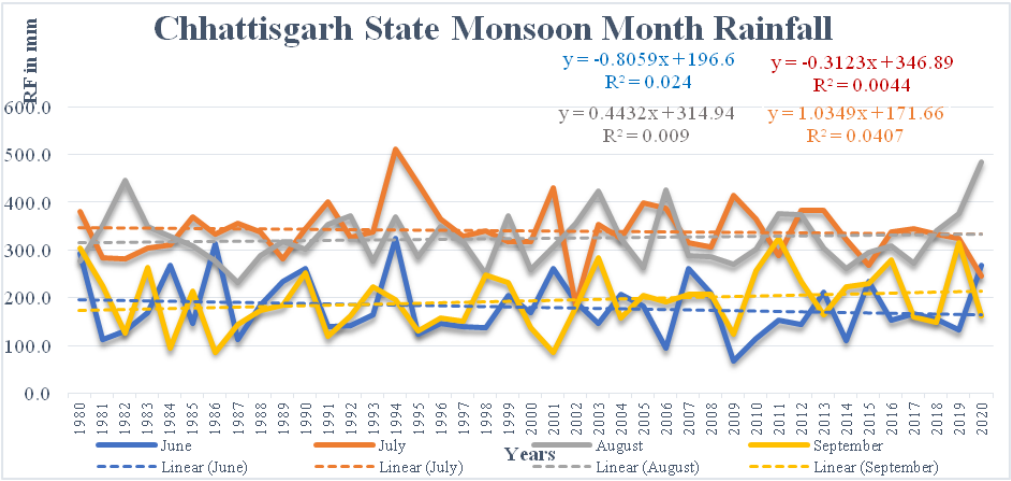

Fig. 1. Chhattisgarh State's Monsoon Months Rainfall

Table 1. Mean rainfall (mm) and coefficient of variation of the state for the monsoon months, southwest monsoon and annual rainfall

Chhattisgarh	June	July	August	September	Monsoon	Annual
Mean (mm)	184.2	348.8	332.3	198.2	1063.6	1209.1
	(15.23)	(28.84)	(27.48)	(16.39)	(87.96)	(100.00)
CV (%)	33.5	15.9	16.6	30.6	9.9	9.9

Source: Derived from analysis

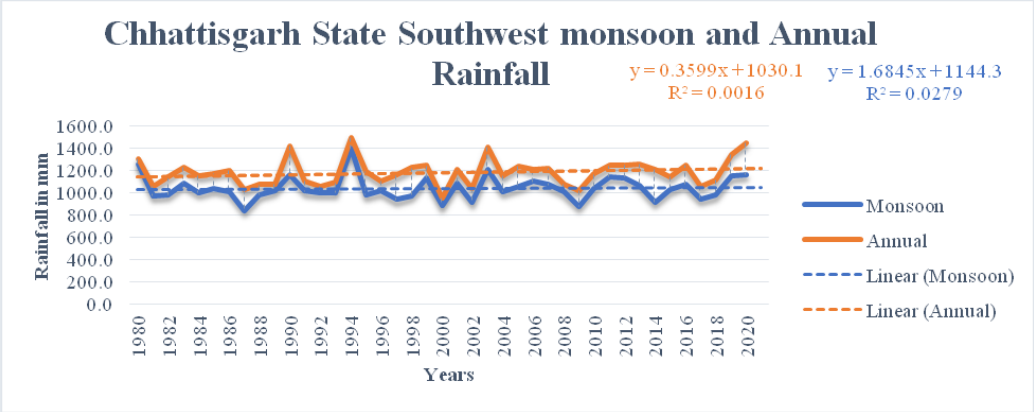

Fig. 2. Chhattisgarh State Southwest monsoon and Annual Rainfall

While June and July show decreasing trends in monthly rainfall, August and September show non-significantly increasing trend. Rainfall both seasonally and annually, is on a positive trend. The year 1994 had the highest June and July rainfall during the previous 40 years (324.9 mm and 511.6 mm, respectively), while the year 2020 and 2011 had the highest rainfall in August and September around 484.7 mm and 324.5 mm, respectively. The year 1994 saw the highest annual rainfall of 1495.84 mm and the highest southwest monsoon rainfall of 1401.2 mm. The lowest rainfall amounts were 69.7 mm in (year 2009), 186.1 mm (year 2002), 232.6 mm (year 1987), 87.7 mm (year 2001), 841 mm (year 1987), and 952 mm (year 2000) for June, July, August, and September, SW monsoon season, and annual, respectively.

3.2 District Wise Rainfall Mean, Coefficient of Variation, and Pattern

Table 2 provides rainfall statistics for Chhattisgarh's districts for the annual southwest monsoon season and four monsoon months. Figs. 3 and 4 illustrates the spatial distribution of these statistics. As can be seen, the district of Sukma received the most precipitation overall during the SW monsoon (1512 mm). Around 241-245 mm of rain falls over this district in June, 397-403 mm in July, 404-409 mm in August, 278-382 mm in September, and 1321-1350 mm of rain falls annually over this district during the SW monsoon. Durg district has the lowest annual and SW monsoon season rainfall totals (907 mm and 1024 mm, respectively). Most districts reported more or less consistent rainfall over the years. The Bijapur district recorded the highest annual rainfall, 3144.5 mm, while the Dantewada district had the lowest annual rainfall, 511.4 mm. The Sukma district experienced the most average annual rainfall throughout the research period with 1624.7 mm, and the Balrampur district experienced the lowest average annual rainfall with 1029.5 mm (based on a 17-year data set) [9]. Data collected over 40 years of district rainfall shows that rainfall of June in the district Bijapur and Balrampur are less consistent with coefficient of variation is around 80 percent. rainfall in the Month of July the district Surajpur and Koriya have 46 and 42 percent variation.With 983.1 mm, 1126.4 mm, and 1267.0 mm, respectively, Kabirdham district has the lowest total annual rainfall at 50%, 25%, and 10% chance levels. Kabirdham district got the least rainfall (996.1 mm), while Sukma district receives the highest (1466.6 mm) [10]. in August, Bemetara and Bijapur have variability with 64 and 58 percent. Gariyaband and Bemetara have 70 percent variability in September month during the selected period. Bijapur district has less variability in monsoon and annual rainfall i.e., 34

and 30 percent, respectively which is less as compare to monsoon months.Climate changed situation can adopted by the change in crops and use of new varieties, improved agronomical practices will help to overcome these issues. The use of resource management technology and a change from sole production to a diversified system of agriculture are strongly justified. More support needs to be given to horticulture and agro-forestry [11]. climate change patterns at the state level in India from 1951 to 2010. The Mann-Kendall test and Sen's slope approach were employed. The results showed that rainfall in Himachal Pradesh decreased throughout the winter (December-February), monsoon (June-September), and post-monsoon (October-November) seasons, and increased during the summer (March-May). They also reported that the state's annual mean rainfall had decreased [2].

Table 2 shows that the district-wise minimum rainfall variability of June, July, August, and September is around 37 percent (Kanker) and 22 percent (Jashpur). Kabirdham district has a 25 percent variability in August and September. District Kanker and Raigarh varied around 14 percent for monsoon and annual rainfall [12,13].

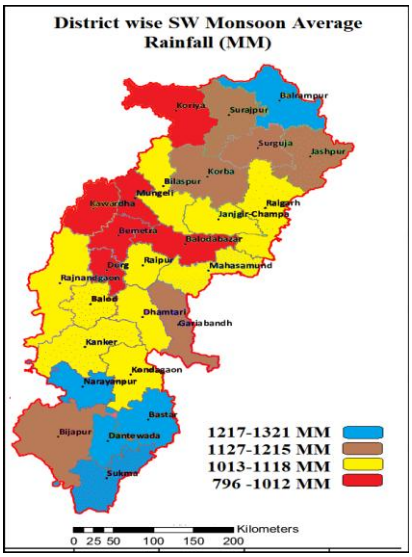

Fig. 3. Mean Pattern of SW Monsoon over Districts

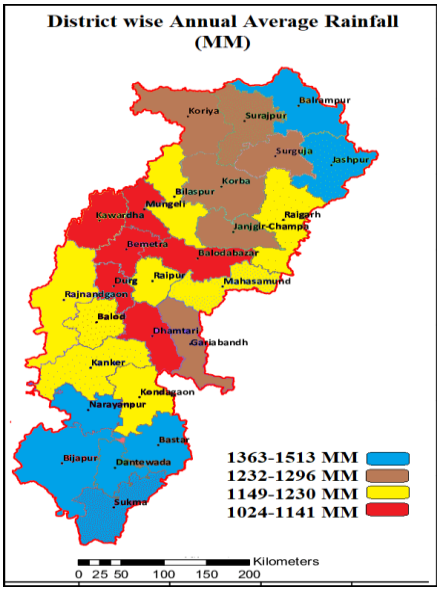

Fig. 4. Mean Pattern of Annual Rainfall over Districts

Table 2. District-wise rainfall statistics of Chhattisgarh state for the four monsoon months, southwest monsoon season, and annual (Mean rainfall in mm, Coefficient of variation in Percent)

Districts	June		July		August		September		Monsoon		Annual	
	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV	Mean	CV
Balod	179.9	60.0	324.3	33.3	352.1	35.5	198.0	55.3	1054.3	18.5	1165.0	18.8
Balodabazar	173.0	59.8	336.2	30.0	277.3	30.5	183.6	42.7	970.1	16.6	1071.7	15.3
Balrampur	195.0	80.9	432.3	36.3	370.4	37.7	231.0	61.8	1228.7	23.3	1375.5	23.7
Bastar	241.7	45.0	358.8	29.0	376.5	30.7	240.1	46.8	1217.2	21.8	1501.7	20.6
Bemetara	253.6	46.4	278.5	38.4	181.0	64.1	82.2	63.8	795.3	29.2	1079.6	21.6
Bijapur	181.1	80.0	432.4	42.6	384.6	58.0	217.2	52.6	1215.3	34.6	1388.7	30.3
Bilaspur	184.8	54.6	347.0	38.7	331.9	31.4	192.2	50.4	1055.9	19.7	1219.6	17.5
Dantewada	195.9	53.2	402.9	34.8	444.7	35.8	237.4	50.9	1281.0	21.8	1404.7	20.9
Dhamtari	171.2	54.2	316.5	36.1	319.5	43.5	206.0	51.4	1013.2	19.2	1144.1	18.5
Durg	140.5	59.3	319.4	37.7	279.6	36.3	167.4	58.5	906.9	20.4	1024.4	20.4
Gariyaband	221.7	67.3	360.8	39.9	374.8	45.1	224.3	70.3	1181.7	26.1	1287.6	25.1
Janjgir-champa	151.5	64.5	385.8	26.4	364.2	26.7	216.8	44.6	1118.2	16.4	1232.4	16.7
Jashpur	207.2	44.2	401.4	22.4	362.3	28.7	235.3	37.0	1206.2	15.9	1363.0	15.5
Kanker	181.5	37.7	331.9	33.7	359.4	26.3	185.1	42.0	1057.9	14.2	1150.8	16.8
Kabirdham	140.4	44.0	315.5	34.1	288.0	25.9	193.7	37.3	937.5	18.8	1076.6	17.9
Kondagon	209.2	59.6	340.0	31.7	343.8	33.2	180.6	47.7	1073.6	23.0	1291.7	24.3
Korba	185.2	78.1	378.1	31.5	361.6	30.5	208.1	55.8	1132.9	23.3	1253.4	23.6
Koriya	168.6	65.5	334.0	42.9	313.0	38.6	196.8	61.0	1012.4	32.8	1256.8	24.7
Mahasamund	170.0	61.4	358.7	28.4	351.4	31.2	218.8	54.9	1098.8	17.1	1196.5	16.1
Mungeli	159.4	52.9	322.3	31.7	285.2	27.7	185.2	46.4	952.0	17.0	1073.5	17.3
Narayanpur	237.7	49.8	396.0	36.7	442.9	36.0	209.5	57.5	1286.1	23.7	1455.2	21.4
Raigarh	182.2	38.9	368.5	28.8	330.3	30.2	213.5	45.9	1094.5	13.7	1230.7	14.2
Raipur	175.2	49.0	348.1	32.0	316.7	28.6	212.9	50.7	1053.0	19.3	1169.6	18.3
Rajnandgaon	176.9	68.4	352.0	31.3	332.3	27.8	184.6	42.5	1045.8	16.8	1149.6	17.5
Surguja	185.0	79.7	374.4	42.8	355.7	34.5	212.2	58.5	1127.2	27.9	1296.9	26.1
Sukma	241.4	50.5	397.7	38.4	404.2	43.5	278.3	60.6	1321.7	28.3	1513.4	24.8
Surajpur	209.2	71.9	411.8	46.5	330.6	41.5	202.3	62.5	1153.9	24.8	1272.2	23.0

Source: Department of Agrometeorology,IGKV Raipur

4. CONCLUSION

The Analysis resulted in more variation in the months of of June and September rainfall, considered the most suitable time for farming in Chhattisgarh. It may therefore be developed such varieties which can withstand the early and late onset of monsson as well as the offset of monsoon for chhattisgarh farming situations. According to district-wise four monsoon month , monsoon season and annual rainfall statistics, the variation of rainfall is most recorded in the month of June in districts such as Balrampur, Bijapur, Korba, and Surguja; the variation is slightly less in the months of July and August; and the variation is greatest in the month of September. In some districts, such as Balrampur, Korea, Sukma, and Surajpur, this variation is greater than 60 percent, even after the monsoon has ended in India. In regions with more pronounced climate change, crops with a short growing season should be chosen and can withstand a lack of or excess precipitation. This variation has been recorded in the districts of Northern Hills and Bastar Plateau during the months of June and September. Hence, Cultivation of coarse cereals such as maize, jowar, and minor millets such as Kodo Kutki, ragi, etc. would be the beneficial in these districts. According to the climatic conditions of these regions, agricultural scientists should develop varieties of minor millets and maize.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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