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Rainfall based crop planning in rain shadow districts of Chhattisgarh state by using rainfall and crop data

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Abstract
An attempt has been made to study the impact of variability and trend of rainfall on crop production and productivity of different crops at two rain shadow districts of Chhattisgarh state viz. Rajnandgaon and Kawardha by using long term rainfall (1963-2015) and crop (2000-2014) data. An average annual rainfall of 1104 mm and 984 mm has been observed in Rajnandgaon and Kawardha districts respectively and annual CV varies between 14 % and 18 %. It can be concluded from the analysis that the main rainy months in all the stations were during June to September with least variability. In other months, the rainfall was very less and corresponding CV was more than 100 % in all the stations. High rainfall variability indicates its effect which may lead to instability in the crop productivity. Rice and gram are the predominant crops and it shows an increasing trend of productivity in both the districts. Productivity trend for rice crop was increasing @ 54.5 kg/ha/yr and 46.6 kg/ha/yr and chickpea was increasing @ 25.6 kg/ha/yr and 30.6 kg/ha/yr in Rajnandgaon and Kawardha districts respectively. The area and production of soybean crop showed a statistically significant increasing trend but increasing productivity trend was not significant. The area, production and productivity trend of Pigeonpea crop was showing a non-significant value for both the districts. The trend analysis of sugarcane crop showed a significant increasing trend in Kawardha district.

Keywords: Rainfall variability, rainfall trend analysis, crop trend, crop planning

Introduction

One of the most interesting aspects of weather is rainfall and its variance from one place to another. When mountains are nearby, the rainfall amounts can vary significantly within a small distance. There are two basic effects on precipitation caused by mountains. There is the "orographic" effect and the "rain shadow" effect. The orographic effect happens on the windward side of a mountain. The rainfall amounts increase dramatically as we move farther up the mountain on the windward side. The other effect is the rain shadow effect. The rain shadow effect is where precipitation amounts drop significantly on the leeward side of a mountain. A rain shadow is an area of land that receives reduced precipitation due to proximity to mountain ranges. The mountains block the passage of rain producing weather systems, casting a shadow of dryness behind them. The condition exists because as warm moist air rises through "orographic lifting" to the top of a mountain range or large mountain, it expands and cools to the point that the air reaches its dew point. At the dew point, moisture condenses onto the mountain and it precipitates precipitation onto the windward side and a top the mountain. The air descends on the leeward side and moving air due to the process of precipitation has lost already much of its initial moisture. Descending air typically gets warmer in the process on the leeward side of the mountain, creating an arid region.

Some of the examples of rain shadow areas can be seen in the country. In the western side of the Western Ghats, the maximum rainfall is getting along the Konkan coast and the Eastern side becomes a rain shadow region. Thus Kerala comes under the heavy rainfall regime and maximum state of Tamilnadu falls in the rain shadow region. The analysis of the observed rainfall pattern over the region has been done with the climatological data set of India Meteorological Department. The normal annual rainfall of Tamilnadu is about 945 mm where as Kerala receives an average annual rainfall of 3107 mm. The mean seasonal analysis of rainfall shows that Kerala gets 68% of annual rainfall (202 cms) in south-west monsoon period while Tamilnadu gets 30% of their annual rainfall (32 cms) in that period. In winter season 4% of annual rainfall received under rain shadow region of Tamilnadu while it is 1 % in Kerala. Even the amount of rainfall received in Kerala is almost same as the rainfall of Tamilnadu in the other three seasons (Spring, Autumn and Winter).

Chhattisgarh is located in the middle-eastern part of India. That is why the state has a Tropical Monsoon climate or Dry Sub-Humid climate, similar to the rest of the country. The Tropic of Cancer line passes through the northern part of Chhattisgarh (Surguja-Koriya districts), that is why the summer is very hot, while the winter is quite cold. Due to its location in the middle-eastern part of India, the impact of the sea doesn't reach Chhattisgarh, because of which it receives lesser rainfall as compared to the coastal regions. The nature of the rainfall here is of the monsoon type. Most of the rainfall occurs in the state from June to September, and December and January witness some rainy cyclones. The highest rainfall occurs because of the monsoon winds rising from the Bay of Bengal. The amount of rainfall decreases gradually from the east to the west. The highest rainfall in the state is in the Abujhmadh Mountains. It experiences an annual average rainfall of 187.5 centimeters. The northern and western parts of Kawardha are surrounded by Maikal mountain ranges of Satpura.

Rainfall analysis is important in view of crop planning for any region. During monsoonal period more than 75% of annual rainfall is received over a major portion of the country. The shortage of water results from uneven distribution of rains, significant gaps between rain events and field water losses rather than from low seasonal or annual rainfall totals. Although water in form of precipitation is available freely and right at the site where it is to be used, yet so tenuous and delicate is the balance between the demand for water by crops and its supply by precipitation that even short term deficit periods often reduce the production significantly (Gupta *et al*. 1990) [2]. Rainfall studies, particularly its variability and trend analysis can give more information for crop planning in any 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. Here seasonal rainfall and annual rainfall trend analysis for Rajnandgaon and Kawardha district has been undertaken in western part of the state as these are basically rain shadow areas due to Satpura-Maikal range as well as due to decreased intensity of monsoonal rain in the western part of the state. Therefore, it has been interesting to study rainfall trend analysis in these rain shadow areas.

Materials and Methods

Study area

The present study is confined to Chhattisgarh, a newly created state which came in to existence on November 1, 2000 as a result of bifurcation from the state of Madhya Pradesh. C.G. state situated in eastern India which is located between $17^0 41'$ N and $24^0 45'$ N latitudes and $79^0 30'$ E and $84^0 15'$ E longitudes. It is surrounded in the west by M.P. and Maharashtra, in the north by M.P., in the east by Odisha and Jharkhand (the new state separated from Bihar) and in the south by Andhra Pradesh. Chhattisgarh state located in central India covers total area of about 13.5 million hectares. Much of the information about the rainfall climatology of any region is mostly based on weekly, monthly, seasonal and annual rainfall data that are derived from daily rainfall recorded at individual stations. The analysis was carried out with 6 stations (Rajnandgaon, Mohala, Khairagarh, Gandai, Chhuria and Ambagarh Chowki) under Rajnandgaon district and only one station under Kawardha district. For this study different softwares available in department of Agrometeorology such as Mann-kendell, weather cock software etc. were used for analysis of trend and rainfall variability. The amount of rainfall received at periodic intervals like weeks, month, season etc. indicate distribution. Crop planning strategies have been developed by using crop and weather data of selected region.

Data for the study

Station wise daily rainfall data was obtained from the Department of Agricultural Meteorology, IGKV, Raipur. Efforts had been made to investigate the basic statistics and trends of rainfall in two districts of Chhattisgarh by analysing long term data of rainfall. This study was conducted at Department of Agrometeorology by using Mann-kendell software and through weather cock software developed by CRIDA, Hyderabad (Rao *et al*., 2011) [8]. For analysis of rainfall at two selected districts i.e. Rajnandgaon and Kawardha, the daily rainfall data of 7 stations having long term records were considered and crop data with regard to area, production and productivity (yield) for rice and other crops grown in this two districts was obtained and used in the present study for strategic crop planning for such districts. The data required for analysis were available from 2000-01 to 2014-15.

Results and Discussion

Mean annual rainfall variability and rainy days

The mean annual rainfall of 1104 mm was recorded in Rajnandgaon district with coefficient of variation of 14 % where as in Kawardha district it was 983.8 mm was with coefficient of variation of 17 %. Mean annual rainy days of 80 with 20% variation was observed in Rajnandgaon district where as in Kawardha district it was 56 days with coefficient of variation of 18 %.

Table 1: Mean annual rainfall and rainy days, its S.D and C.V for Rajnandgaon and Kawardha districts

Districts	Annual Rainfall			Annual Rainy Days		
	Mean (mm)	S.D. (mm)	C.V. (%)	Mean (days)	S.D. (days)	C.V. (%)
Rajnandgaon (1998-2015)	1104	152	14	80	11	14
Kawardha (1963-2015)	983.8	164	17	56	10	18

Variability of seasonal rainfall and rainy days

Out of mean annual rainfall of 1104 mm in Rajnandgaon district, south west monsoon received 1039.2 mm with 72 rainy days of coefficient of variation 12 percent and 11 percent respectively (table 4.8). However rest of seasons received the mean rainfall of less than 50 mm with coefficient of variation of more than 90 percent. This indicates that there is high variability of rainfall observed in all the seasons except south-west monsoon season. There is more uncertainty in sowing of crops at that time. Where as in Kawardha district mean annual rainfall of 983.8 mm was observed out of which south- west monsoon received 854.7 mm with coefficient of variation 18 percent where as 47 rainy days of 19% CV.

Season	Districts	Rainfall			Rainy Days		
	Rajnandgaon	Mean (mm)	S.D. (mm)	C.V. (%)	Mean (days)	S.D. (day)	C.V. (%)
Winter (Jan-Feb)		8.2	8	102	1	1	144
Summer (Mar-May)		13.4	15	112	2	2	120
South West (Jun-Sep)		1039.2	130	12	72	8	11
North East (Oct-Dec)		43.6	40	92	5	4	78
Annual		1104	152	14	80	11	14
Winter (Jan-Feb)	Kawardha	27.3	31	112	2	2	115
Summer (Mar-May)		34	36	107	3	3	100
South West (Jun-Sep)		854.7	155	18	47	9	19
North East (Oct-Dec)		68	63	93	5	4	79
Annual		983.8	164	17	56	10	18

Rainfall trend analysis

Time trend analysis of annual and seasonal rainfall

For trend analysis, data are available from 1998 to 2015 and 1963 to 2015 in Rajnandgaon and Kawardha districts respectively. The annual rainfall trend of both districts is showing a non-significant value (fig. 1 and fig. 2). The time trend equations of annual rainfall from the data have been worked out and are shown below table. Deka *et al.* (2008) [1] found that the decreasing trend rate in the annual rainfall at Jorhat is significant. Further an increasing trend at Dibrugarh, Lakhimpur, Jorhat and Guwahati and a decreasing trend at Tezpur and Nagaon in Brahmaputra Valley of Assam has been observed. Haris *et al.* (2010) [3] reported that rainfall is showing an increasing trend at four stations of Bihar state in last 45 years.

Table 3: Time trend equation of annual rainfall for Rajnandgaon and Kawardha

Districts	Period	Equation	R^2
Rajnandgaon	1998-2015	Y= 8.076x + 1026	0.080
Kawardha	1963-2015	Y =0.918x + 958.9	0.007

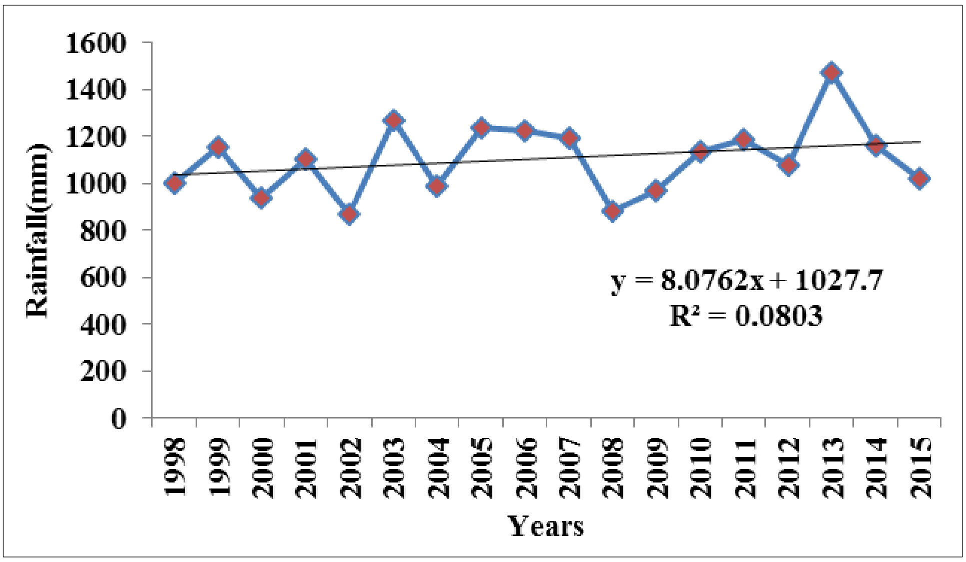

Fig 1: Graphical representation of Annual Rainfall trend for Rajnandgaon

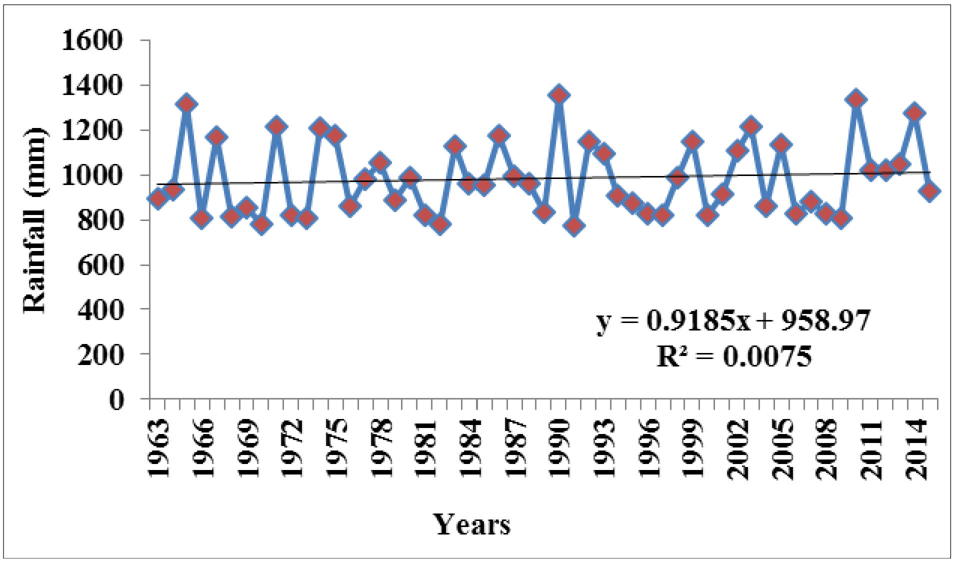

Fig 2: Graphical representation of Annual Rainfall trend for Kawardha

There is a statistically non-significant trend of seasonal rainfall has been found in both the districts. There are four seasons in a year i.e. winter, summer, south-west monsoon period and north-east monsoon period (post monsoon). The seasonal rainfall trends for all the season remains stable in both Rajnandgaon and Kawardha districts.

Mann- Kendall trend analysis for annual and monthly rainfall in Rajnandgaon and Kawardha

No statistically significant trend of annual rainfall has been found in Rajnandgaon and Kawardha districts. Mann-Kendall test of monthly rainfall didn't show statistically significant trend for all months except July and November in Rajnandgaon and August months in Kawardha respectively (Table 4). In Rajnandgaon district, a significantly increasing trend of rainfall is found in the month of July at 10 % LS and a decreasing trend in November month at 1 % LS where as in case of Kawardha district a decreasing trend found in August month at 5 % LS.

Such studies were also conducted by different researchers for different regions. Wadood and Pragyan (2009) analyzed the 40 years rainfall data of Jharkhand state. They found that the annual average of rainfall has shown an increasing trend over the decades, but simultaneous increase in variability also (CV: 13% in 1961-70 to 20% in 1991-2000) which increased the level of uncertainty and possibility of intermittent prolonged dry spells. Rajegowda *et al.* (2009) [7] reported that the Karnataka state's mean annual rainfall was in decreasing trend from 1204 mm (in the first half century 1901-1950) to 1140 mm (during the second half the century 1951-2000). Singh and Dev (2012) analyzed the rainfall data and future trend for the period of 50 years (1959 to 2008) in Saharanpur region of Uttar Pradesh state which is showing the negative trend at present as well as in future projections also.

Table 4: Mann-Kendall test of significance for annual and monthly rainfall trends in Rajnandgaon and Kawardha districts

Rainfall trends	Rajnandgaon	Kawardha
Annual rainfall	0.606	0.798
Monthly rainfall		
January	0.606	0.115
February	-1.326	1.442
March	-0.909	1.189
April	1.061	1.143
May	-0.947	0.974
June	-0.53	1.235
July	1.439*	1.235
August	-0.379	-2.125**
September	0.682	-0.322
October	-0.985	-0.23
November	-1.818**	0.759
December	0.985	0.169

(*- significant at 10% LS, **- significant at 5% LS, ***-significant at 1% LS)

Trend analysis of area, production and productivity for different crops in Rajnandgaon and Kawardha district

There is ultimate target of increasing the productivity of selected crops in these two districts. The area, production and productivity trend for these two districts are analysed for six major crops viz. Rice, Maize, Soybean, Pigeon Pea and Sugarcane. Time trend equations for the crops are shown in table 5.

Table 5: Time trend equation for different crops in Rajnandgaon and Kawardha districts

Crops	Periods	Rajnandgaon district					
		Area		Production		Productivity	
		Equation	R^2	Equation	R^2	Equation	R^2
Rice	2000-2014	Y=2.460x +247.1	0.983**	Y=16.67x+206.2	0.486**	Y=54.47x+847.1	0.393**
Soybean	2000-2014	Y=1.610x +2.119	0.945**	Y=1.514x+2.103	0.586**	Y=12.55x+816.6	0.045
Maize	2000-2014	Y=-0.002x+1.377	0.000	Y=0.057x+1.120	0.228	Y=43.4x+831.9	0.547**
Arhar	2000-2014	Y=-0.115x+4.779	0.147	Y=-0.017x+1.948	0.008	Y=6.989x+419.8	0.120
Gram	2000-2014	Y=2.634x+16.81	0.986**	Y=2.973x+6.521	0.862**	Y=25.75x+561.3	0.442**
Sugarcane	2000-2014	Y=0.002x+0.011	0.381*	Y=0.045x-0.192	0.216	Y=33.32x+1828.	0.185
		Kawardha district					
		Area		Production		Productivity	
		Equation	R^2	Equation	R^2	Equation	R^2
Rice	2000-2014	Y=0.55x+90.2	0.772**	Y=4.985x+70.51	0.538**	Y=46.57x+799.4	0.466**
Soybean	2000-2014	Y=2.895x-1.845	0.931**	Y=2.927x-1.365	0.648**	Y=28.06x+716.5	0.177
Maize	2000-2014	Y=-0.05x+3.174	0.668**	Y=0.111x+2.323	0.355**	Y=60.86x+691.3	0.593**
Arhar	2000-2014	Y=-0.077x+5.499	0.230	Y=0.013x+2.074	0.013	Y=8.746x+378.1	0.201
Gram	2000-2014	Y=2.045x+42.87	0.787**	Y=3.208x+17.18	0.735**	Y=30.57x+461.4	0.492**
Sugarcane	2000-2014	Y=0.200x+1.425	0.524**	Y=0.673x+2.406	0.474**	Y=198.3x+1359.	0.243*

Crop planning

Based on the results obtained from above analysis, the following recommendations for the region have been made to increase the production and productivity of rice and other crops in per unit area per unit time.

- About approximate 80 per cent of the total average annual rainfall concentrated in the south west monsoon and received during a short span of two to three months between June to September.
- Despite advance technology, still monsoonal rains influence the food grain production to a considerable extent. Kharif food grain production is adversely affected due to monsoon break or failure.
- The crops already sown with the advent of monsoon are also adversely affected due to dry spells, which result in soil moisture stress. The onset and withdrawal of monsoon influence the crop growing season and selection of crops to a large extent.
- Rainfall received during summer (March-May) season can be utilized for summer ploughing to make the land ready for final field preparation.
- Harvesting and storage of excess rainfall received during period of south west monsoon season can be used in

drought and dry spell situations as per intensity and frequency from year to year and good crop can be harvested.
- If there is well distributed rainfall in sufficient quantity then this stored water can be utilized to grow second crop in *Rabi* season.
- This rainfall variability studies can help to plan conservation of excess water and its utilization during their peak requirement.

Rainfall studies, particularly its variability and trend analysis can give more information for rainfed region crop planning. 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. Daily rainfall and rainfall on different timescale plays a great role in weather phenomena in tropical countries and helps to determine the agricultural land use potential and hydrological investigations. Further, a precise understanding of agro -climatic conditions is a pre-requisite for efficient crop planning in any given region and this type of understanding is of more relevance in rainfed area where crop productions depend on vagaries of monsoon and other climatic parameters. Here seasonal rainfall and annual rainfall trend analysis for Rajnandgaon and Kawardha district has been undertaken in western part of the state as these are basically rainshadow areas due to Satpura-Maikal range as well as due to decreased intensity of monsoonal rain in the western part of the state. Kumar *et al.* (2004) [5] studied the Impact of Climate on Indian Agriculture which is highly dependent on the spatial and temporal distribution of monsoon rainfall. This paper presents an analysis of crop–climate relationships for India, using historic production statistics for major crops (rice, wheat, sorghum, groundnut and sugarcane) and for aggregate food grain, cereal, pulses and oilseed production.

Conclusions

High rainfall variability indicates chances of instability in the crop productivity. Low CV value indicated that the rainfall was stable in the months of July and August but again the CV increased in the month of September which creates water stress condition during reproductive and maturity stages of crops due to intermittent dry spells. About approximate 80 per cent of the total average annual rainfall concentrated in the south-west monsoon and received during a short span between June to September. Despite advance technology, still monsoonal rains influence the food grain production to a considerabl eextent. Kharif food grain production is adversely affected due to monsoon break or failure. If there is well distributed rainfall in sufficient quantity then this stored water can be utilized to grow second crop in *Rabi* season. This rainfall variability studies can help to plan conservation of excess water and its utilization during their peak requirement.

From the present investigation it was confirmed that there was no changes found over a period of 1998-2015 and 1963-2015 in Rajnandgaon and Kawardha districts respectively. There was a significant trends found during recent decades.

Looking into the challenges in rained crop cultivation in rain shadow districts of Chhattisgarh that our future agricultural planning must be taken into account of this rainfall. Short duration but high yielding varieties need to be developed in this region. Soybean + Pigeonpea intercropping is also found promising which can be used as a sustainable tool for crop production. Increased production of sugarcane crop mainly due to introduction of high yielding varieties, improved agronomic practices and state government policy support.

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