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Impact of seasonal rainfall trend and its variability on crop production in rainshadow districts of Chhattisgarh: A case study in Kawardha district

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Abstract
In this research work we studied the impact of seasonal rainfall trend and its variability on production of major crops at Kawardha district of Chhattisgarh state. For this study, long term rainfall data (1962-2015) and crop data (2000-2014) were used. The mean annual rainfall of 983.8 mm was recorded in Kawardha with coefficient of variation of 17 %. The coefficient of variation was lowest during monsoon season like the CV during July and August is less than 40 % where as it is more than 50 % but less than 60 % in June and September months. 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. During south-west monsoon period mean of 46 days was observed with coefficient of variation of 19 percent. Rest of seasons received mean rainy days of less than 6 with coefficient of variation more than 70 percent. Rest of seasons received the mean rainfall of less than 70 mm with coefficient of variation of more than 90 percent. The CV of less than 100 percent was found during the season of north-east monsoon period. The seasonal rainfall pattern in this area is similar to annual rainfall as more than 90 per cent of annual rainfall is received during kharif season. There is a statistically non-significant trend of seasonal rainfall has been found in this district but a significant rainfall trend was found in the month of August at 5 % level of significance. The area, production and productivity of all the selected crops are showing a significant increasing trend with some exception in Maize (decreasing trend of area), Soyabean (productivity trend is not significant) and arhar (non-significant value).The main crop production of the district was concentrated on this seasonal rainfall pattern. So, water harvesting and storage is more convenient steps towards this.

Keywords: Seasonal rainfall trend, seasonal rainfall variability, crop trend analysis and rainfall based crop planning

Introduction
The amount of rainfall received over an area is an important factor in assessing the amount of water available to meet the various demands of agriculture, industry, irrigation, hydroelectric power generation and other human activities. Therefore, distribution of rainfall in time and space is an important factor in determining the economical status of a region or a state or a nation. The south west monsoon (June-Sept.) is the principle source of rain in the entire country. 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]. Hussain *et al*. (2016) [3] analyzed the inter-annual and intra-seasonal rainfall variability in Pakistan using daily rainfall data during the summer monsoon season (June to September) recorded from 1980 to 2014. The variability in inter-annual monsoon rainfall ranges from 20% in northeastern regions to 65% in southwestern regions of Pakistan. The analysis reveals that the transition of the negative and positive anomalies was not uniform in the investigated dataset. In order to acquire broad observations of the intra-seasonal variability, an objective criterion, the pre-active period,

active period and post-active periods of the summer monsoon rainfall have demarcated. The analysis also reveals that the rainfall in June has no significant contribution to the increase in intra-seasonal rainfall in Pakistan. The rainfall has, however, been enhanced in the summer monsoon in August. The rainfall of September demonstrates a sharp decrease, resulting in a high variability in the summer monsoon season. A detailed examination of the intra-seasonal rainfall also reveals frequent amplitude from late July to early August.

Rainfall analysis is important in view of crop planning for any region. 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. Here, seasonal rainfall trend analysis for 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.

Rainfall analysis is important in view of crop planning for any region. Rainfall studies, particularly its variability and analysis of number of rainy days 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.

By keeping above facts in mind, the present investigation has been carried out with the following objectives:

1. To study the annual and seasonal trend of rainfall in rain-shadow districts of Chhattisgarh State.
2. To estimate the rainfall variability in rain-shadow districts of Chhattisgarh.
3. To develop suitable strategy for increasing production and productivity in rain-shadow districts of Chhattisgarh.

Materials and Methods

Study area and Data base

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 170 41' N and 240 45' N latitudes and 790 30' E and 840 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. 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 under Kawardha district by using weather cock software available in department of Agrometeorology. 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 variability of rainfall in Kawardha district of Chhattisgarh by analysing long term data of rainfall. This study was conducted at Department of Agrometeorology by using weather cock software developed by CRIDA, Hyderabad (Rao *et al*., 2011) [6].

Results and Discussion

Mean seasonal variation of rainfall and rainy days for Kawardha district

The seasonal rainfall pattern in this area is similar to annual rainfall as more than 90 per cent of annual rainfall is received during kharif season. Mean annual rainfall of 983.8 mm was observed in Kawardha district out of which south- west monsoon received 854.7 mm with coefficient of variation 18 percent. However, rest of the seasons received the mean rainfall of less than 70 mm with coefficient of variation of more than 90 percent. The CV of less than 100 percent was found during the season of north-east monsoon period. In this district, the numbers of mean annual rainy days also varied from 55 to 60 days. During south-west monsoon period mean of 46 days was observed with coefficient of variation of 19 percent. Rest of seasons received mean rainy days of less than 6 with coefficient of variation more than 70 percent. (Table 1).

Table 1: Mean, SD and CV of seasonal rainfall and rainy days for Kawardha districts

Season	Districts	Rainfall			Rainy Days		
	Kawardha	Mean (mm)	S.D. (mm)	C.V. (%)	Mean (days)	S.D. (day)	C.V. (%)
Winter (Jan-Feb)		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

It can be very well observed than as assured monsoonal month starts, CV value comes down. Mean monthly rainfall was more in the month of August (283 mm) with lowest CV (33 %) in this district. (Fig. 1). The CV during July and August is less than 40 % where as it is more than 50 % but less than 60 % in June and September months. The CV is more than 100 percent in rest of the months.

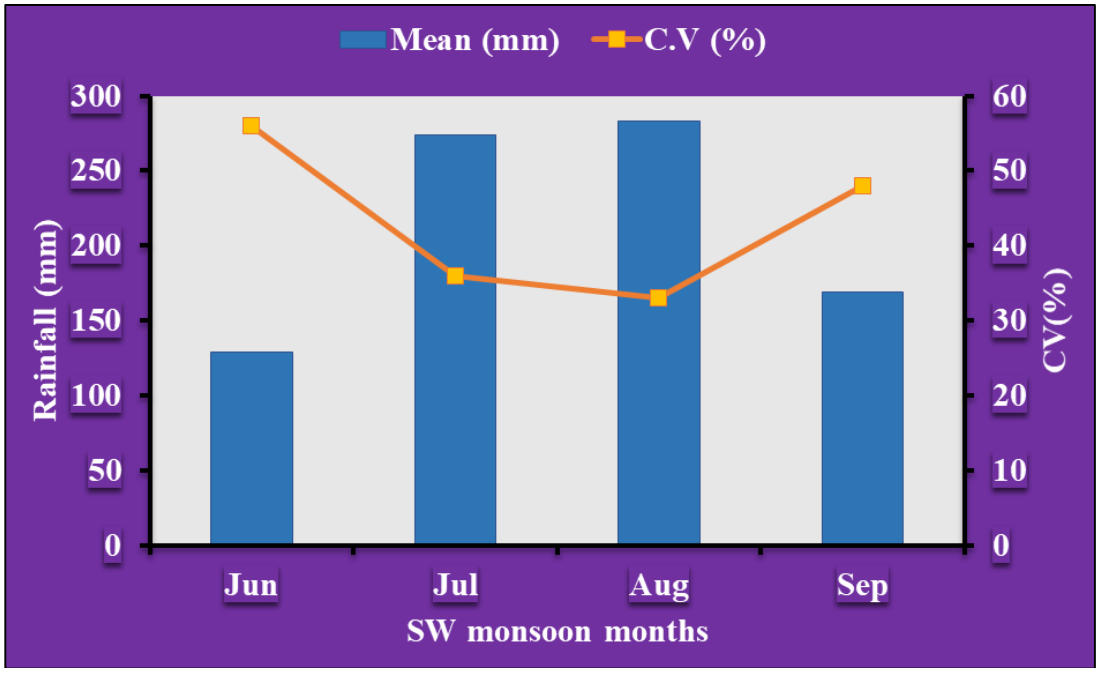

Fig 1: Graphical representation of seasonal rainfall variation for Kawardha district

Rathod and Aruchamy (2010) presented the study of rainfall characteristics of the Coimbatore District, which includes the spatial distribution and variability through different seasons, precipitation ratio and frequency occurrences. The study is based on 49 years of the monthly rainfall data for 33 rain gauge stations. While analyzing the long term average of monthly and annual rainfall, the annual rainfall of the district is 1242 mm, of which the winter, summer, southwest and northeast monsoon record 2.07, 14.97, 46.13 and 36.83 mm respectively. The station Upper Niradam receives the highest rainfall of 4655 mm whereas Krishnapuram records the lowest of 414 mm. The annual variability ranges from 21.16 percent to 52.28 percent. The south, south-west and north-western parts of the district experience the heavy rainfall whereas the least rainfall areas are the east, northeast and south eastern parts of the district.

Rainfall trend analysis

Time trend analysis of seasonal rainfall

Kumar *et al.* (1992) [4] reported that in India in the case of rainfall, the observed southwest monsoon seasonal rainfall at all India level does not show any significant trend. Understanding the regional level of rainfall trend using long period data is of immense importance for countries like India, where the economy is dependent on agriculture. Raghvendra (1974) [5] studied the trends and periodicities of rainfall in sub- divisions of Maharashtra State viz., Konkan, Madhya Maharashtra, Marthwada and Vidarbha sub- divisions. They found that the coefficient of variations was about 20 percent for the annual and monsoon rainfall except, in Marathwada where it was 25 percent. The annual and monsoon rainfall in the state followed the normal distribution for their yearly frequencies. The trend as revealed by fitting of orthogonal polynomials is shown as a quadratic curve for the annual and monsoon rainfall of Konkan and Madhya Maharashtra, sub-divisions on either side of the Western Ghats.

There is a statistically non significant trend of seasonal rainfall has been found in this district. 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 and are shown from fig. 2,3,4,5. In Kawardha district, when we considered the monsoon season month a decreasing trend of rainfall was found in the month of August which is statistically significant at 5 % level of significance.

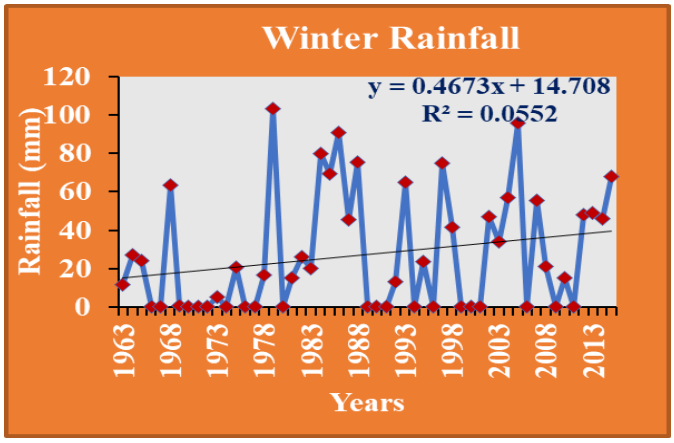

Fig 2: Graphical representation of winter season rainfall trend

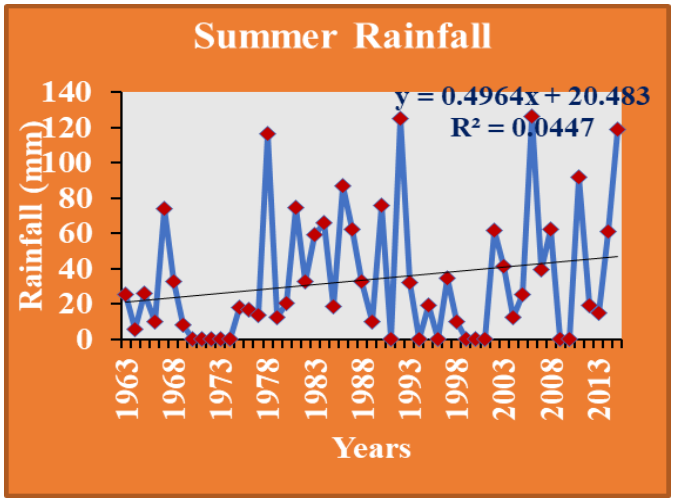

Fig 3: Graphical representation of summer season rainfall trend

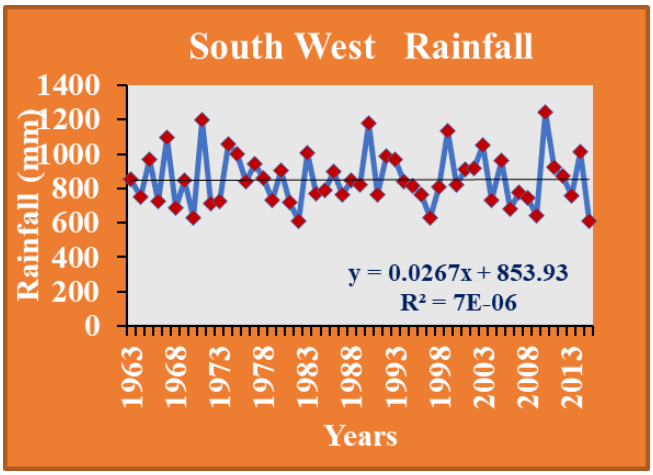

Fig 4: Graphical representation of SW monsoon season rainfall trend

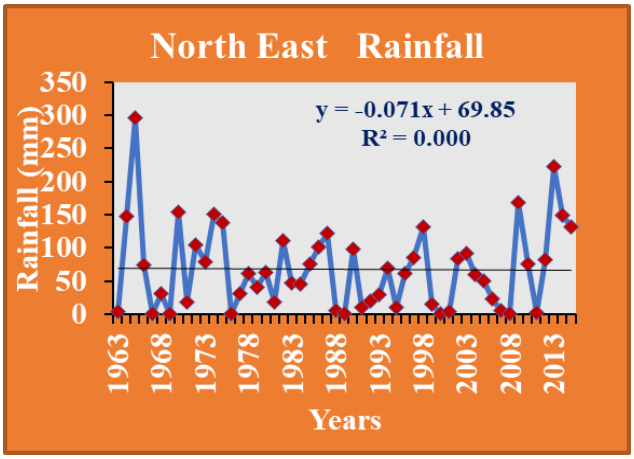

Fig 5: Graphical representation of post monsoon rainfall trend

Analysis of area, production and productivity trend of different crops in Kawardha district

The area, production and productivity trend of different crops of Kawardha district are shown in the Table 2. Rice is the pre-dominant crop of the district. In this district, the highest area under rice crop was found in the year 2014 (102000 ha) and lowest in 2000 (90000 ha). The area was constant during the year 2002 to 2006. Here, there was not uniform increasing or decreasing trend of acreage was found because of the fact that during the years 2012 and 2013, sugarcane is another competing crop with rice which is also having an increasing trend in this district. Sugarcane crop coverage has led to decreasing rice crop coverage particularly in these two years. It can be seen from regression equation that increase in rice acreage is @ 550 ha/year which might be possible due to conversion of wasteland to other existing land use.

Basically, two kinds of cropping situations are there in this district, one is soybean based cropping system and second is rice based cropping system. Looking into the trend line, significant in the The highest area under this crop in Kawardha district was found in the year 2013 (36040 ha). We can say that there is steady and significant growth in the soybean crop acreage due to intervention of state government policies. The rate of increase in soybean acreage is @ 2895 ha/year in this district.

There has been a decreasing trend of pigeonpea area is found particularly due to rising soybean and rice acreage. The area was highest in the year 2000 (6220 ha) for Kawardha district where as lowest in 2008 (3690) and 2011 (3800 ha). However, after reaching the lowest coverage in 2011, there is steady increasing coverage area for this crop due to state government policies interventions for increasing acreage under pulse and oilseed crops. On the basis of database 2000-2014, Pigeonpea acreage is declining @ 77 ha per year.

The highest area under maize crop was found in the year 2000 (3300ha). Later it decreased in rest of the years. Maize crop is a viable cereal crop after rice during kharif season. However, during recent times, this crop is also being taken during the rabi season. The trend line indicates that crop acreage is declining @ 50 ha per year. The possible reason for this may be that the crop is facing competition from other crops like soybean and rice crops.

The area under sugarcane crop was very less as compared to other crops. Only few of the district of Chhattisgarh are growing sugarcane crop mainly for domestic consumption and for generating cash income. The highest area was found in the year 2014 (5750 ha) which was higher than other years. The lowest area was found in the year 2000 (1130 ha). The increase in area has been observed over the years due to installation of sugar mill in Kawardha district.

Chickpea is the main rabi crop in the district as it occupies maximum area than other pulse crops. There is a significantly increasing trend of chickpea acreage found in Kawardha district. The highest area under chickpea was found in the year 2014 (73800 ha) which was very high as compared to other year. The lowest area was found in the year 2000 (35800 ha). After 2004 onwards, the area under this crop is found out to be more than 60000 ha. The area is rising @ 2045 ha per year. The area covered under different crops are shown in Fig. 6.

The production was higher during the year 2012 as compared to other years in Kawardha. The highest production was found in the year 2011 (155000 tonnes) where as lowest in 2000 (47000 tonnes). Exceptionally the production was more in the year 2006 which was second highest (130000 tonnes) year. There was a drastic decrease in production which has been found in the year 2009 (79000 tonnes) which is mainly due to drought situation prevailing in the state in this particular year.

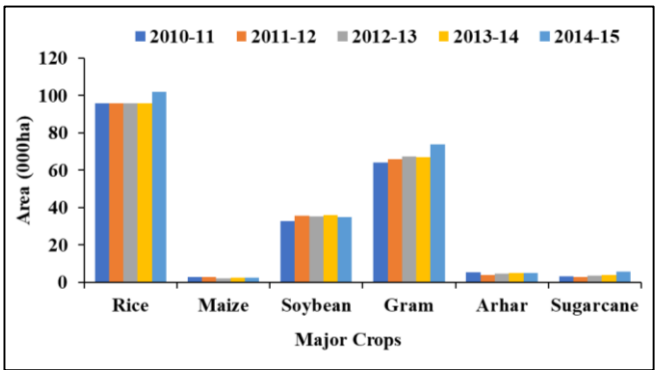

Fig 6: Graphical representation of area covered under major crops of Kawardha District

A quantum jump in soybean production in Kawardha district can be observed mainly because of significantly increasing area of soybean in this district. It can be seen that soybean production is increasing @ 2927 metric tonnes in this district. The Pigeonpea/Arhar production of the district was highest in the year 2014 (Approximately 3220 tonnes). The production has not been raised more than 3000 tonnes from 2000 to 2013. The time trend equation shows a decreasing trend of production which is statistically not significant and is declining @ 130 tonnes per year in this district. The Maize production of the district was highest in the year 2013 i.e. 5070 tonnes. One significant feature has been found that

inspite of declining acreage of maize in Kawardha district, production has been rising @ 111 tonnes per year which can be considered as technological impact. This also indicates the suitability of this crop in cropping system.

Sugarcane production was highest in 2011 (18015 tonnes). After 2012, a drastic change in production has been found. Here, the production is rising @ 673 tonnes per year which can be considered a significant feature. Increase in production can be attributed to state government policy support, introduction of high yielding varieties and improved agronomic practices due to which significant jump has been observed in sugarcane production. Further analysis has also shown that technological inputs have contributed to increase in sugarcane production. An increasing trend of sugarcane production had been found. There has been productivity increase @ 198.3 kg/ha per year which can be taken a significant figure and this has led to quantum jump in the production of sugarcane crop in Kawardha district. The highest sugarcane production was found in the year 2014 (78200 tonnes) which was very high as compared to other year. The lowest area was found in the year 2000 (12100 tonnes). In the year 2010, 2011 and 2012, the production is more than 50000 tonnes where as in rest of the year it is less than 50000 tonnes. The production is rising @ 3208 tonnes per year. The production and productivity of different crops are shown in Fig. 7 and Fig. 8

Table 6: Time trend equation for different crops in Kawardha district

		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*

(*-Significant at 5 % level and **-Significant at 1% level)

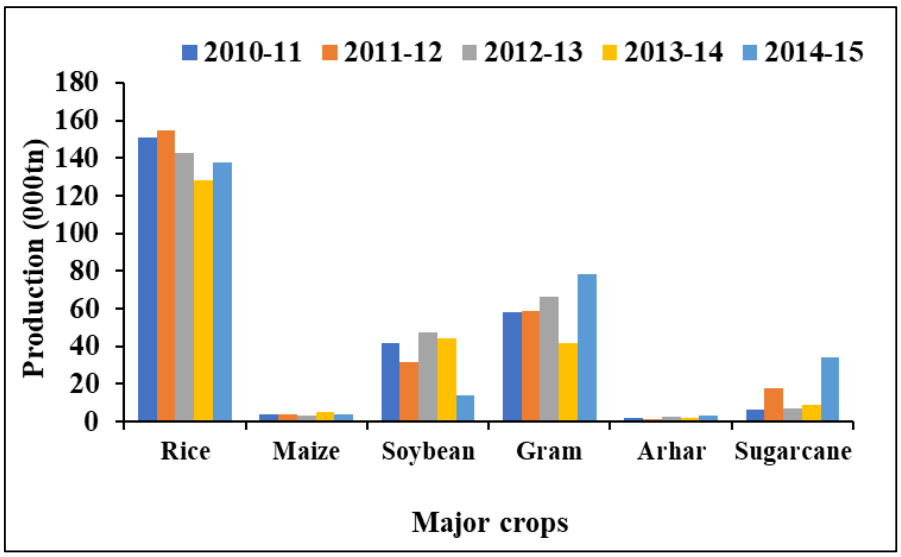

Fig 7: Graphical representation of major crop production

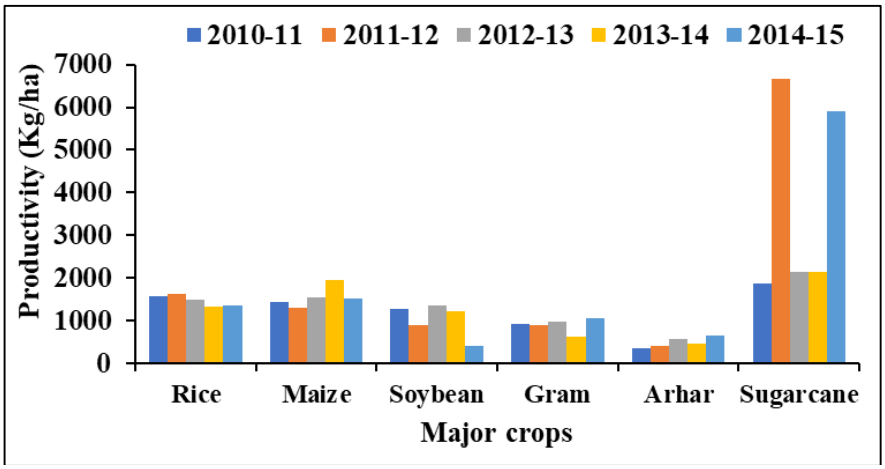

Fig 8: Graphical representation of productivity of major crops

The Rice productivity was more during the recent year 2010, 2011 and 2012 with a highest productivity of 1620 kg/ha in 2011. This can be interpreted in terms of better technical interventions like increased fertilizer consumption, irrigation

sources and better availability of high yielding varieties. Later, it decreased in 2013 and 2014. The productivity of 1400 kg/ha was found in the year 2006 which was higher than previous year. This indicates that productivity has been affected by different weather situations particularly intermittent dry spell situations.

The soybean productivity of Kawardha district was highest in the year 2012 (1350 kg/ha) where as lowest in 2014 (400 kg/ha). Low productivity particularly during this year was mainly due to drough situation. Upon observation of trend line, it can be seen that there is steady and increasing pattern of soybean productivity due to technological advancement as well as expansion of soybean crop acreage. The productivity trend of Pigeonpea crop for Kawardha district showed a statistically non significant increasing trend. There is a need to identify and develop the short duration high yielding varieties of this crop so that the production becomes sustainable for this crop in these regions. However, soybean + Pigeonpea intercropping is also found to be promising which can be used as a sustainable tool for sustainable crop production. The productivity of maize crop in was highest during the year 2013 (1958 kg/ha) followed by 1540 kg/ha and 1510 kg/ha in 2012 and 2014 respectively where as lowest in 2000 (662 kg/ha). The maize productivity is rising @ 60.86 kg/ha per year.

The Sugarcane productivity was highest in 2011 (6667 kg/ha) and lowest in 2000 and 2001 (1950 kg/ha). There has been productivity increase @ 198.3 kg/ha per year at 5 % LS. From the figure 8, it is clearly showing that the sugarcane productivity during last five year was very high as compared to other crops especially in Kawardha district because of improved irrigation facility. Chickpea productivity was highest in 2014 (1060 kg/ha) and lowest in 2000 (340 kg/ha). There has been productivity increase @ 30.6 kg/ha per year. It leads to interpretation that there has been a quantum jump in the gram crop productivity. The increasing trend of chickpea productivity for both the districts is statistically significant.

Crop Planning Based On Rainfall Pattern of Kawardha District

Chaudhary (1999) [1] studied the variations of rainfall, rainy days etc. for understanding and adopting the suitable cropping system and scope for application of modern techniques for increased cropping intensity and crop productivity. Cropping system of any area can be decided by several climatic parameters. Here, we are mainly concerned with the rainfall characteristics among all the parameters. There is comparatively less amount of rainfall found in Kawardha districts than other districts as this is under rain shadow area of Chhattisgarh. Rice is one of the most important cereals of Chhattisgarh and occupies a large part of its area than other crops. Mostly farmers follow mono-cropping of rice but now a days inter-cropping, multiple cropping and double cropping have a great importance in agriculture for sustainable crop development. Inclusion of legumes in the cropping system is beneficial in many ways like legumes fix atmospheric nitrogen in root nodules and thus improve the nitrogen status of the soil. It saves upto 25 % of recommended level of nitrogen application to the associated cereals when grown as inter-crop. The crop residues and root nodules of legumes release nitrogen during decomposition for the use of the succeeding crop.

Crops require soil moisture during the growth and development phase. The only source for soil moisture is rainfall under rainfed conditions. Since, crops depend on rainfall, they must be adjusted to a particular period during which rainfall is assured. The distribution of rainfall in both the seasons is erratic and unpredictable. The whole year is divided into four seasons viz. south-west monsoon, post-monsoon, winter and summer or pre-monsoon which is coinciding with the agricultural seasons i.e. kharif, rabi and summer. The kharif season is nothing but the south-west monsoon or autumn while rabi coincides with post monsoon and winter seasons. In summer, the cultivable land under seasonal crops is kept fallow in many regions of Chhattisgarh state. Almost all the field crops are sown or planted based on the onset of monsoon. The crops are never in shortage of water during the first crop season if monsoon is normal otherwise crops are grown under soil moisture stress even in kharif because the number of rainy days and the amount of rainfall received are less than that of the average rainfall and rainy days of a particular district. In rabi season, few rains are received as a result of which almost all the crops suffer due to soil moisture stress if irrigation facilities are not available during rabi. Hence, irrigation facilities are pre-requisite to raise successful crop during rabi as well as summer.

Like rainfall, rainy days also plays an important role in crop planning. A day is called as rainy day if the rainfall of that day is at least 2.5 mm. A week during which the weekly rainfall is less than 35 mm with less than 4 rainy days is called dry spell. The interval between the onset of effective rains and the commencement of the first dry spell is known as wet spell (the effective rain may be a rainfall spell of more than 35 mm spread over a period of 7 days with at least four rainy days to begin with). Most of the farmers construct huge bunds in the rice fields and they impound this water for rice cultivation to avoid the uncertainty factor of monsoonal rainfall. This practice of making huge bunds often becomes adverse for rice crop seedlings as higher bunds submerge the rice seedlings and hence growing of tall, long duration, photo-sensitive varieties which can sustain higher water levels has become a traditional practice of rice cultivation in this area. Farmers in this region grow long duration varieties under *Broadcast Biasi* system. These varieties mature by mid-November whereas the south western monsoon withdraws in mid-September. Therefore, terminal drought at the reproductive stage of the rice crop is a recurring feature and moreover, water stresses are a common feature during growth cycle of crops. Under this *broadcast biasi* system, rice seeds are broadcast in a ploughed field immediately after onset of the monsoon around mid-June. After about 30 to 35 days of onset of monsoon when sufficient water is impounded in the fields, the fields are ploughed in the standing crop. This is called *biasi* or *bushening*. The uprooted seedlings are transplanted approximately at the same site (*in situ* transplanting) after biasi and this operation is called *chalai* in local language. The biasi operation is done mainly to control weeds, to create semi-puddled conditions, to arrest percolation losses, to decrease the initial high population and to slightly adjust the plant population through *chalai*.

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 considerable extent. 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. Looking into the challenges in rainfed crop cultivation in rainshadow 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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