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Divya Shrivastava
M.Sc. (Ag), Department of Agro-Meteorology, College of Agriculture, Indira Ghandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Shri JL Chaudhary
Senior Scientist, Department of Agro-meteorology, College of Agriculture, Indira Ghandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Corresponding Author:
Divya Shrivastava
M.Sc. (Ag), Department of Agro-Meteorology, College of Agriculture, Indira Ghandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh, India

Effect of monsoon onset and withdrawal on rice production in Chhattisgarh

Divya Shrivastava and Shri JL Chaudhary

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Abstract
The variability in monsoonal rainfall has affected agricultural production worldwide. Changes in the onset, withdrawal and distribution of monsoon rainfall have made a risky preposition for rice cultivation. In Chhattisgarh rice cultivation is mainly rain-fed and obviously prone to south-west monsoon variability. The aim of this research was to analyze the probable impact of monsoon onset and withdrawal variability on rice production in different agro-climatic zones of Chhattisgarh during a 29-year period (1989-2017). On the basis of correlation analysis we found that there is significant relationship between withdrawal dates of monsoon and rice production. The r-values was 0.491 (In CPZ), 0.594 (In BPZ) and 0.472 (In NHZ) for the correlation between monsoon withdrawal dates and rice production. The highest value of correlation co-efficient was found for Bastar plateau zone (r = 0.594). These co-efficient are significant at the 1% level of significance in all three agro-climatic zones for withdrawal dates of SWM (south west monsoon) and rice production during 1989-2017. In comparison of average rice production data under different categories of monsoon onset-withdrawal, we found that late withdrawal conditions are favorable for rice production and productivity.

Keywords: Monsoon onset, withdrawal, production

1. Introduction
Rainfall pattern governs the overall cropping pattern, productivity and sustainability of agriculture enterprise. For the natural and anthropogenic ecosystems of the country, monsoon rains are of great importance. Therefore, an important field of monsoon research is to determine onset and withdrawal dates using objective criteria and to understand their variability. For research, society and utilities, accurate real-time determination of the onset and withdrawal dates of the southwest monsoon across India is essential. The importance of rain-fed agriculture in India can be measured by the fact that it contributes to 40 percent of the food production of the country and accounts for much of the domestic field with coarse cereals (85 percent), pulses (83 percent), oilseeds (70 percent) and cotton (65 percent); and maintains 60 percent of the total cattle population (Venkateswarlu and Prasad 2012) [10]. The onset of the Indian Summer Monsoon (ISM) has a significant impact on agriculture, especially because the rain-fed agriculture crop calendar depends largely on the southwest monsoon onset dates (Rosenzweig and Binswanger 1992) [6]. Detailed knowledge of rainfall patterns helps to schedule the calendar of crops and design the structure of water storage to meet the need for irrigation for the duration of drought periods. With its variability in onset dates and withdrawal dates, the southwestern monsoon has a major effect on the country's agricultural production (Sabeerali *et al.* 2012) [9]. In both acreage and rice production, India is a major player. It has the largest area (42.9 million hectares), comprising approximately 27.1 percent of the world's total rice-growing region.
During the southwestern monsoon season between June and September, 78 percent of the annual precipitation over India is estimated (Rao, 2015) [8]. The 'amount and distribution' of rainfall are very important features affecting agricultural production in the rainfed regions (Subash *et al.* 2002). Strong downpour at the start of South west Monsoon, abrupt mid-monsoon break (Chand *et al.* 2012; Mishra 2012) [1, 4], and early withdrawal of monsoon rain raise the frequency of dry spell (DS) at different growth stages of rice. As a result, rice production often suffers from intermittent water stresses during peak growing stages and even contributes to occasional crop failure.

Agriculture operation in India starts with the onset of south-west monsoon. If the start of monsoon is postponed, the transplantation of rice seedlings will also be postponed and the rice output eventually reduced.

In the event of delayed onset of monsoon delays crop sowing resulted in decreased yield. Similarly, early withdrawal of monsoon impacts production, particularly when the kharif crops are at critical growth phases of grain formation and grain development, due to serious moisture stress. Therefore, the unpredictable nature of the monsoon creates a great deal of suffering for farmers, the general population and livestock, and these factors have a negative effect on the economy. As mentioned above, the frequency of monsoon varies. Sometimes the onset may be delayed, or there may be a long break immediately after the onset. At times, the onset and distribution may be very good, with almost a month of dry belts in between. In addition, monsoon often withdraws early in the first or second week of September. Thus, the strength of the summer monsoon rains and the date of the onset of the monsoon are both important factors for the economy of the country, as it is the main season for rice planting. The behavior of monsoon across Kerala decides the total output of paddy during kharif season, beginning from June to September, as it is grown under rain-fed conditions. All-India's SW monsoon for the 1961-98 period was about 5 percent lower than the average of the previous 30-year period (Ramanathan *et al*., 2005) [7]. Many studies have indicated that the production of kharif crops is low when monsoon rainfall is poor. As uncertainties fluctuate in the onset, stability and withdrawal pattern make a risky preposition for crop production.

Chhattisgarh is located in the east central part of the country. The state has been separated into three distinct agro-climatic zones; *viz*: Chhattisgarh Plains, Bastar Plateau and Northern Hills and it covers 50.52, 28.62 and 20.68% area respectively. Chhattisgarh's mean annual rainfall is 1188 mm with a 26 percent coefficient of variation. Chhattisgarh receives 89 percent rainfall during the month of June-September (south-western monsoon season). The state receives 1056 mm rainfall during south west monsoon. South west monsoon arrives at Chhattisgarh on 15th June in southern parts of Bastar and later on extend over the entire state. It is completely withdrawn from the entire state up to mid of October. The state of Chhattisgarh extends over an area of 13.51 million hectares with 5.8 million hectares of gross cropped area. Rice is the main crop and Chhattisgarh's central plains are known as Central India's rice bowl. Rice is cultivated in Chhattisgarh state in about 3.8 million hectares, of which over 80 percent are rainfed. Rice cultivation in Chhattisgarh is largely dependent on south west monsoon. About 74% area of Chhattisgarh plains, 97% area of Bastar plateau and 95% area of Northern hills are rain-fed, having the paddy as lead crop (Chaudhary *et al.* 2015) [2]. A key determinant of the growing seasons and the forms of agriculture practiced is rainfall. For example, in Chhattisgarh, rice is the main crop and is highly susceptible to the variability of rainfall. Rice, Chhattisgarh's staple food, is the rural population's most significant source of jobs and income. Therefore, there is rising concern that the variability of the monsoon will affect the productivity of paddy crops. Taking these variations into account and the effects of future variability of the monsoon on the production of rice, this study aimed to determine the effect of the onset and withdrawal dates of the monsoon on the production of rice in different agro-climate zones in Chhattisgarh.

2. Material and Methods

2.1 Location of Study Area

The analysis was carried out with agro climatic zones of Chhattisgarh. The state has three agro climatic zones, the plains of Chhattisgarh, the plateau of Bastar and the region of Northern hills, spreading over 13.60 million hectares of geographical area. For this study, we have selected three representative stations: Jagdalpur (Bastar Plateau zone), Raipur (Chhattisgarh Plains zone) and Ambikapur (Northern Hill zone).

2.2 Data set

The basic data used in the present study are the production and productivity of rice, and onset-withdrawal dates of southwest monsoon. Agricultural statistics have been collected from the Ministry of Agriculture. Zone wise monsoon onset and withdrawal data were collected from the Raipur Meteorological Center for the period 1989-2017. The analysis was carried out for the kharif season rice.

2.3 Methods

Two methods have been used to examine differences in rice production due to variations in onset and withdrawal of monsoon. In the first approach, we compared average rice production of 29 years with average rice production of different categories of monsoon onset and withdrawal years. For the classification of years into the early, normal and late onset-withdrawal year of the monsoon, we used simple statistical methods such as mean and standard deviation.

The mean date of onset and withdrawal of the monsoon was calculated by using the equation as shown below:

$$X = \frac{(\sum x_i)}{n}$$

Where

Xi = dates of onset of effective monsoon.

n = Total number of years.

The standard deviation of Xi dates of onset and withdrawal of monsoon as computed by using the following equation.

$$\text{Standard deviation} = \frac{\sqrt{\Sigma(x - \bar{x})^2}}{n-1}$$

Where

$\bar{x}$ = Mean onset date

n = Number of years

x = Actual onset date

In the second process, we used simple correlations method to examine the impact of onset and withdrawal of monsoon on rice production.

2.4 Correlation co-efficient

Correlation is a statistical method that can demonstrate whether and how strongly pairs of variables are associated with each other. It indicates the extent to which two or more variable fluctuate together. It is used to explain the linear relationship between two continuous variables.

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

3. Results

For comparison purpose of rice production data, calculation of average production and productivity will be desirable. The average values (1989-2017) of these tow parameters are calculated and summarized in Table 1.

3.1 Effect of monsoon onset in different agro-climatic zone

Bastar plateau zone

It has been seen that in early onset years of monsoon, there is no indication of increased rice production compared to the 29-year average value of rice yield. However in this tribal belt due to late onset of monsoon, average paddy production has come down to 757 thousand tones which is 2.32% lower than average value (775.1 thousand tones). In normal monsoon onset years, the average value of rice yield is 778.12 thousand tones, which is 0.38 per cent higher than the average value of rice production over 29 years. As a result, farmers are losing about 2.7% of paddy production in late onset condition, compared to normal onset years. As far as the effect of monsoon on rice productivity is concerned, it can be seen that there is some advantage to the farmers in early monsoon onset years, and paddy crop productivity increased positively to 1273.05 kg / ha.

3.2 Chhattisgarh plain zone

If we see the rice production in normal onset years it is significantly touching an average figure of 3954.80 million tones which is 3.22% higher than 29 year average value (3831.1thousand tones). On the other hand late onset of monsoon is having its adverse impact on rice production mainly because of the fact that late onset has its own impacts on high water requirement crop like rice water demand and other farming operations are adversely affected. In late onset condition production is decreasing 3831.1 thousand tones to 3450.8 thousand tones which is 9.92% less than 29 year average value of rice production (3881.1 thousand tones). As far as impact on rice productivity is concerned it has been observed that in early onset of monsoon, rice production has not increased and it has remained at nominal level.

3.3 Northern hill zone

It can be interpreted from the study that the effect of the onset of monsoon on paddy production in the Northern Hill Region is fortunate and that paddy production appears to be favored in the early onset condition. Production in early monsoon onset years is 425.39 thousand tones while it is 402.91 thousand tones in normal years hence it can be easily interpreted that there is a 5.6 percent increase in average paddy production in early onset years of monsoon. There is highly fortunate situation for rainfed rice production in this belt.

It is the only zone in which rice production has been favored for early onset of monsoon. Detailed analysis for understanding this difference of rice production among different ACZ needs to be undertaken. In early onset conditions it can be very well seen that there is advantages in rain-fed paddy cultivation in terms of paddy productivity with paddy yield of 1156.5 kg/ha. This value is 5.18% more than 29 year average value. This value is 5.18 per cent higher than the average value of 29 years.

Table 1: Zone wise average production and productivity of rice in C.G.

ZONE	Year	Production (000 t)	Productivity (kg/ha)
N.H.Z	1989-2017	408.6	1099.4
C.P.Z.	1989-2017	3831.1	1353.3
B.P.Z	1989-2017	775.1	1242.6

Table 2: Average Production and Productivity of Rice according to early, normal and late 'onset' years of monsoon for different ACZ.

For Northern Hill zone		
Categories	Production	Productivity
Average rice data of Normal onset year	402.9	1093.9
Average rice data of Early onset year	425.3	1156.4
Average rice data of Late onset year	410.1	1071.0
For Chhattisgarh plain zone		
Categories	Production	Productivity
Average rice data of Normal onset year	3954.8	1410.6
Average rice data of Early onset year	3741.6	1341.6
Average rice data of Late onset year	3450.8	1209.6
For Bastar plateau zone		
Categories	Production	Productivity
Average rice data of Normal onset year	778.1	1251.6
Average rice data of Early onset year	769.3	1273.0
Average rice data of Late onset year	757.0	1198.5

3.4 Effect of monsoon withdrawal in different agro-climatic zone of Chhattisgarh

Bastar Plateau Zone

As far as impact of variation in monsoon withdrawal on rice production in Bastar plateau ACZ is concerned, it can be seen from table 3 that rice production in situation of early withdrawal of monsoon has decreased; rather rice production is increased in late withdrawal of monsoon. It has been seen that in early withdrawal of monsoon, there is adverse impact on rice production because of moisture stress. However in this tribal belt due to early withdrawal of monsoon average paddy production has come down to 595.13 thousand tones. In normal years, it is 741.44 thousand tones. As far as the impact of monsoon withdrawal on rice productivity is concerned, it can be very well seen that in late withdrawal years, there is some advantage for paddy crop productivity.

3.5 Northern Hill Zone

The effect of withdrawal of monsoon on paddy production has been analyzed from the Table 3. In Northern hill zone the impact of withdrawal of monsoon on paddy production is favorable and paddy production occurs to be good in late withdrawal condition of monsoon. During the study period the average production of rice in late withdrawal years is 536.13 thousand tones while it is 404.45 thousand tones in normal withdrawal years and 322.9 thousand tones in early withdrawal years. Therefore it can be easily interpreted that there is a 31.2 per cent increase in average paddy production in late monsoon withdrawal years relative to the 29-year average value of rice production (408.6 thousand tones).

3.6 Chhattisgarh Plain Zone

Average rice production for early withdrawal years in CG plains was 3380.70 thousand tones. This value is 11.75% lower than 29 year (1989-2017) average value (3831.15). On the other hand production under late withdrawal of monsoon is 5087.9 thousand tones which is 32.8% higher than 29 year average value (3831.15 thousand tones) and there is no

adverse impact on the rice production. If we see the rice production in normal withdrawal years it is very close to average figure of 29 year average value (3831.15 thousand tones).

Table 3: Average Production and Productivity of Rice according to early, normal and late 'withdrawal' years of monsoon for different ACZ.

For Northern Hill zone		
Categories	Production	Productivity
Average rice data of Normal withdrawal year	404.4	1087.3
Average rice data of Early withdrawal year	322.9	890.3
Average rice data of Late withdrawal year	536.1	1420.4
For Chhattisgarh plain zone		
Categories	Production	Productivity
Average rice data of Normal withdrawal year	3692.4	1307.0
Average rice data of Early withdrawal year	3380.7	1246.6
Average rice data of Late withdrawal year	5087.9	1718.2
For Bastar plateau zone		
Categories	Production	Productivity
Average rice data of Normal withdrawal year	741.4	1187.8
Average rice data of Early withdrawal year	595.1	993.2
Average rice data of Late withdrawal year	1168.6	1827.6

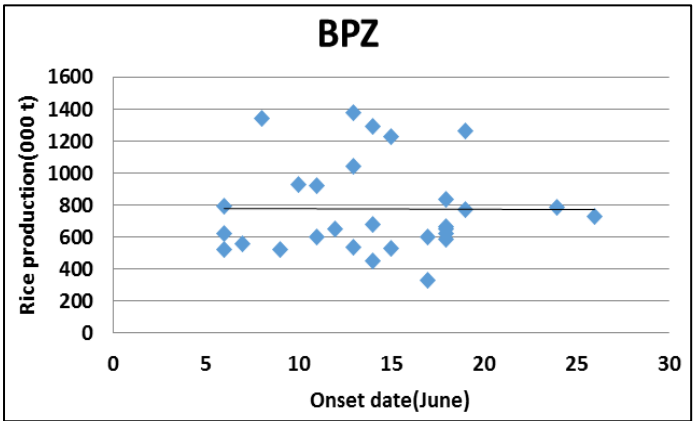
3.7 Correlation analysis

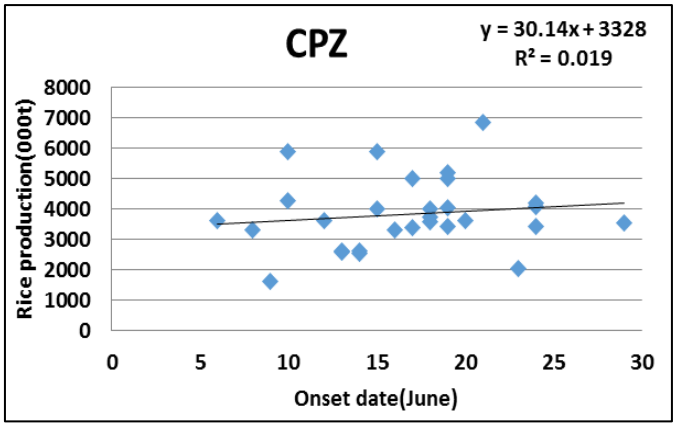
In this study, the correlation analysis has been undertaken to find out the relationship between the monsoon onset-withdrawal and rice production in different A.C.Z. of Chhattisgarh (Fig.1 and 2). Table 4 shows the values of correlation co-efficient between onset dates and paddy production. Correlation coefficients are -0.004 (for B.P.Z.), 0.138 (for C.P.Z.) and 0.086 (for N.H.Z.). A negative correlation has been seen between monsoon onset dates and rice production in Bastar plateau agro-climatic zone (r = – 0.004). From the analysis it is observed that there is non-significant relationship between monsoon onset dates and paddy production.

The relationship between withdrawal dates of monsoon and paddy production has been seen from the Fig 5. It can be observed that there is a strong relationship between withdrawal dates of SWM and paddy production. A strong positive correlation has been seen in all three agro-climatic zones between the withdrawal of the south-western monsoon and the yield of kharif rice. The r-values are 0.491 (for CPZ), 0.594 (for BPZ) and 0.472 (for NHZ). The highest value of correlation co-efficient was found for Bastar plateau zone (r = 0.594). The correlation coefficient is significant at the 1% level of significance in all three agro-climatic zones for withdrawal dates of SWM and rice production during 1989-2017. Therefore it can be said that there are significant effect on rice production due to variability of withdrawal dates monsoon. Early withdrawal of monsoon can easily damage rice production because of moisture stress conditions, as it is the peak period of water requirement for rice.

Table 4: Correlation co-efficient (R2) of rice production and onset withdrawal dates of SWM

Agro-climatic zones	**Correlation co-efficient**	
	Between onset dates of monsoon and rice production	**Between withdrawal dates of monsoon and rice production**
NHZ	0.086	0.472 **
CPZ	0.138	0.491 **
BPZ	-0.004	0.594 **





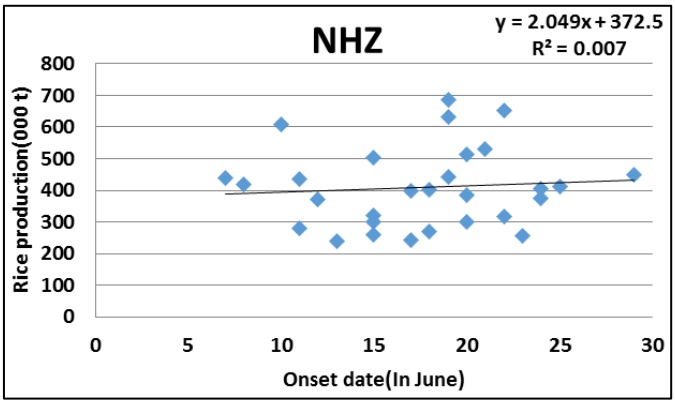


Fig 1: Correlation between onset dates of monsoon and rice production in different ACZ.

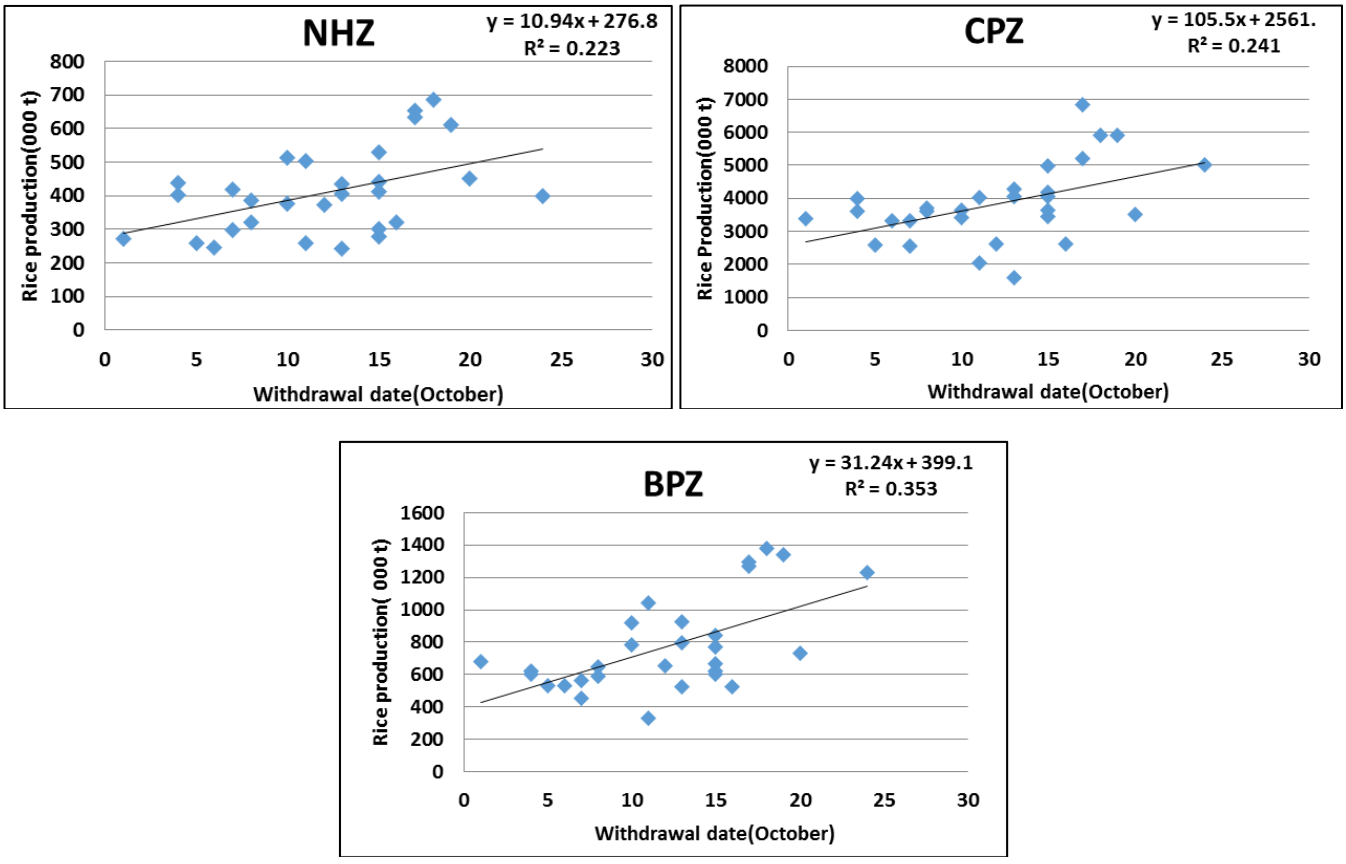


Fig 2: Correlation between withdrawal dates of monsoon and rice production in different ACZ.

4. Discussion and Conclusion

The main effort of this study was to analyze the impacts of the onset and withdrawal variability of the southwest monsoon on the production of kharif rice in Chhattisgarh. The date of onset and withdrawal of the southwest monsoon in Chhattisgarh is important for farmers as it affects the timing of crop sowing and the length of the southwest monsoon season. Comparing average rice production data for different categories of monsoon onset and withdrawal, we found that late monsoon withdrawal conditions are favorable for rice production and productivity. Based on the correlation study, we found that there is a significant association between the date of withdrawal of monsoon and the production of rice. All three agro-climatic zones are showing significant positive correlation co-efficient values at 1% level of significance. This is consistent with the previous research by Mukherjee *et al.* (2014) [4]. They concluded that the yield of rice shows the highest positive association (R2 = 0.60) with total monsoonal rainfall (June to September). Monthly rainfall during 'September' has the highest impact on crop yields. The month of September shows the highest correlation (R2=0.17 to 0.30) followed by July (R2=0.18 to 0.31), August (R2=0.14 to 0.24) and June (R2=0.05 to 0.21). Similar results was found by Kumar *et al*. (2004) [3] who reported that the series of all-India rice production and monsoon rainfall shows a strong (r = 0.77) relationship. In the case of kharif rice production, the correlations with rainfall during individual months are also significant during the period of June-October. The value of correlation-co-efficient was highest for the months of September. In our previous research, we found that there was a delayed trend of monsoon onset and withdrawal over Chhattisgarh after 2004 [3]. Recent research shows that monsoon rainfall in India has become less frequent but more intense. All these changes have an effect on the crop pattern, crop growth and yields of rice in the region. The distribution of rainfall is also changing. Therefore, intensive research should be required to highlight variation on rice production due to variation of southwest monsoon and to guide intensive measures on the perspective of climate change and cultivation of paddy in Chhattisgarh.

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