

# Impact of Rainfall on Rice production of India

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**ABSTRACT:** Rice is a very important agricultural produce in India which is greatly dependent on rainfall. Grown during different times of the year at different regions of the country, the crop heavily relies on the availability of water during different phases of its growth. This study delves into the temporal and spatial correlations of monsoon and post monsoon rainfall on kharif and rabi rice yields respectively. The study shows the unequivocal dependence of kharif production on Summer monsoon with strong responses from Southern Peninsula and Central India. On the other hand, Rabi production is substantially correlated with the precipitation of December of the previous year. Further, the study on the influence of Bay of Bengal cyclones on the rabi production for the states along the east Indian coast shows the constructive relation between the number of cyclones and the Rabi rice production in Odisha.

**KEYWORDS:** Monsoon; Rice production; Cyclones

## I. INTRODUCTION

India is primarily an agrarian economy, with agricultural production contributing to about 14 % of the country's GDP [1,6]. Agriculture forms about 10 % of the total exports. Besides, around 45 % of the total geographical area is under agriculture. Agriculture has an occupational importance from time immemorial, as it became the means of livelihood for about 60 % of the total population of the country.

Precipitation in India is unevenly distributed over time and space. India receives rainfall during the months of June, July, August and September, known as Summer monsoon or South-West monsoon. While around 80 % of the total area of the Indian subcontinent receive this rain, the rest of India receives rainfall during the post-monsoonal period or winter. Fig. 1 shows that the coastal regions along Western ghats and the North East are regions receiving heavy mean annual rainfall of more than 1500 mm. The rain-shadow regions of Western ghats and parts of Rajasthan and Gujarat receive scanty rainfall of less than 750 mm [3].

About 60% of the total land under agriculture depends fully on rain. The rest of them are both rainfed and irrigated. The rainfall received over India during the four summer months from June to September is very critical for the country's economy, that the impact of the deficit of 19 % in the Indian summer monsoon rainfall in 2002 has been estimated to be well over 1 % of the gross domestic production. Summer monsoon rainfall has characteristic break and active phases, owing to its intraseasonal variability. Frequent and protracted break spells during the monsoon season can aggravate drought conditions and hence reduce the crop yield substantially [2,4].

Of all the agricultural produce of India, Rice is the major contributor. Rice is grown at different parts of the year depending on the season of occurrence of rainfall for the region, based on which it is classified as kharif (summer crop) and rabi (winter crop). Earlier studies had shown that there is direct correlation between annual summer rainfall to kharif rice yield [5]. Kharif crop growing season (Jun – Sept) occurs at the same time as the South-West Monsoon. Kharif crops are very significant as more than 50% of the total food grain production is during this period. While Rabi season, which starts after the monsoon, depends mostly on the rainfall received by the fag end of the monsoon period and the stored soil moisture.

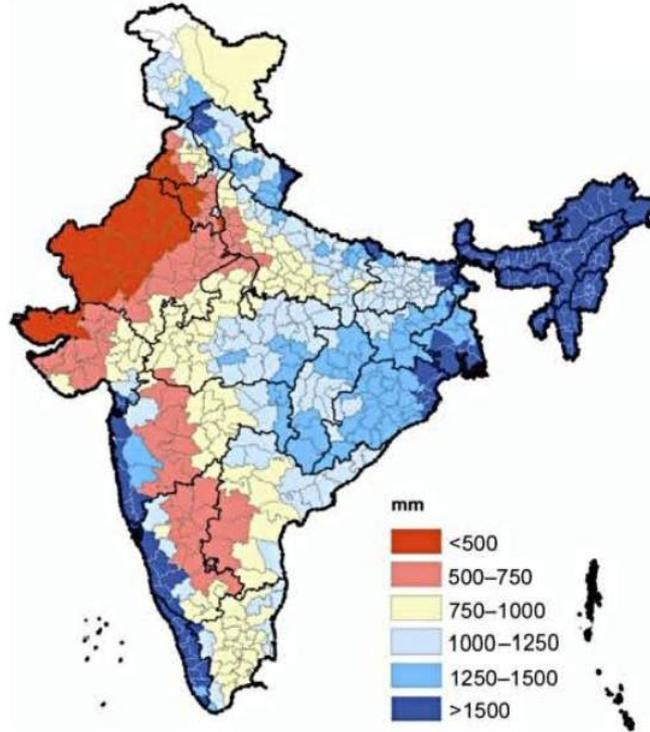


Fig. 1. Spatial distribution of average annual rainfall [3]

## II. DATA

The data of the annual and monthly yield of rice for different years were obtained from Crop Production Statistics Information System, maintained by Agriculture Informatics Division, Government of India. It includes the information such as the area under irrigation, productivity and yield in all the districts of a state, separately for rabi and kharif rice.

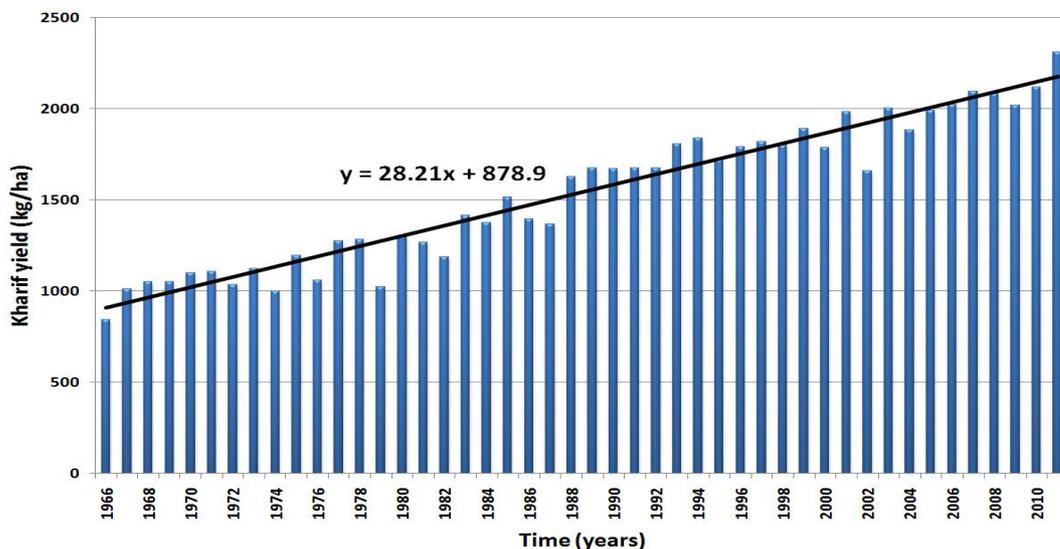


Fig. 2. Total Kharif Rice yield from 1966 to 2011. The trend line (black) shows the steady increase in yield over time.

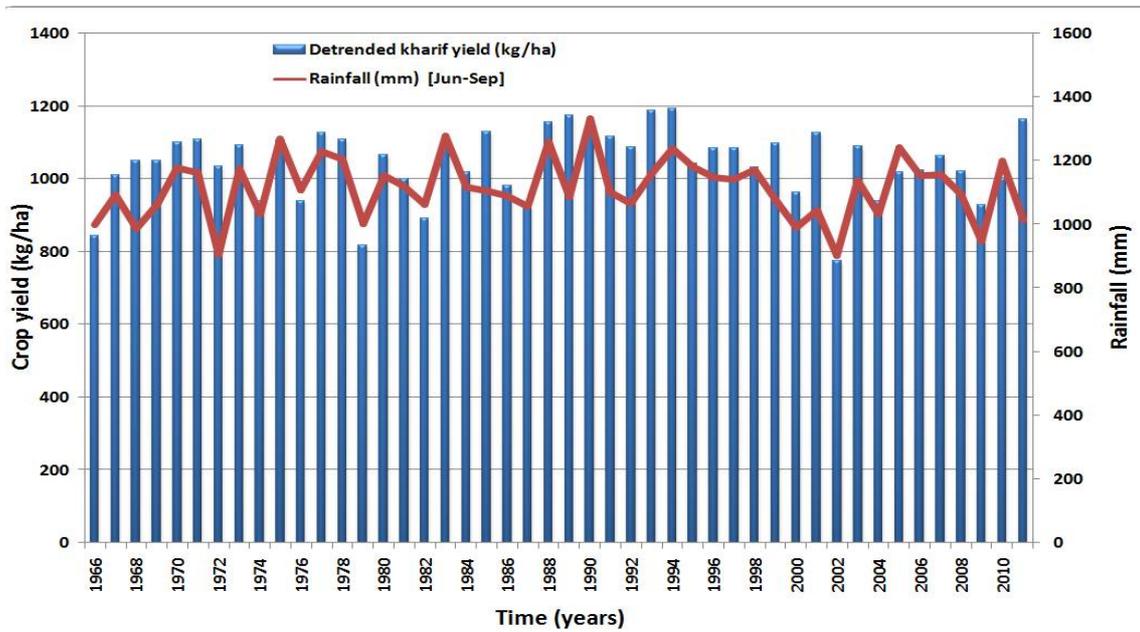


Fig. 3. The detrended Kharif Rice yield and annual rainfall

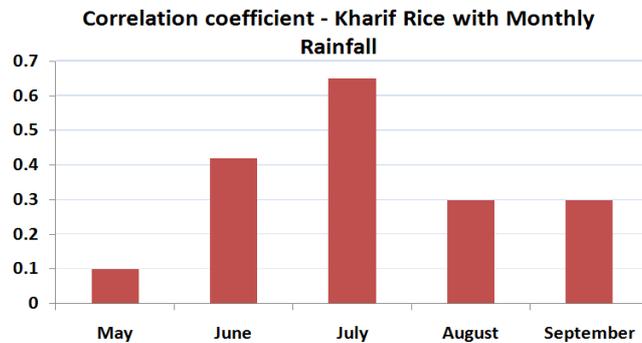


Fig. 4. The correlations between Kharif yield and Summer Rainfall for different months.

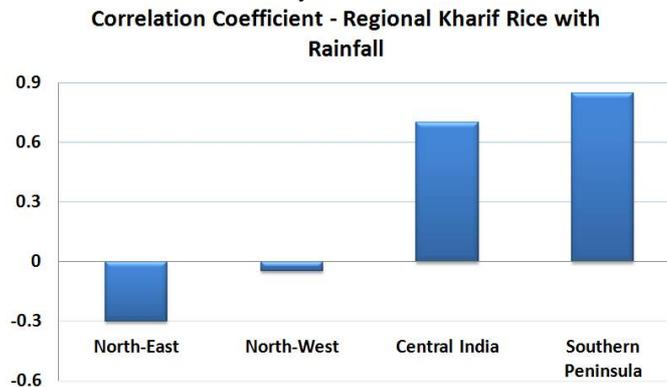


Fig. 5. The correlations between the Kharif yields from different regions and Summer Rainfall.

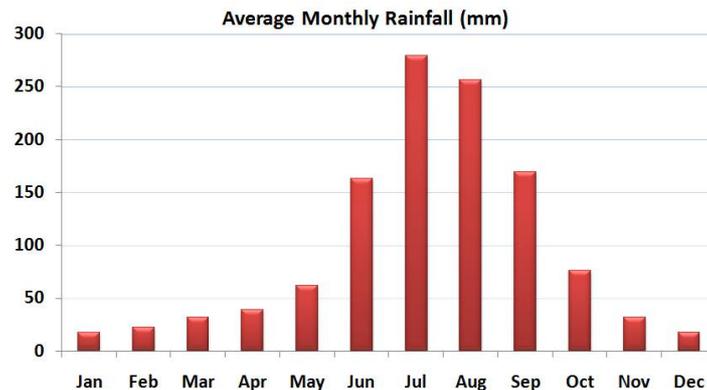


Fig. 6. Annual averaged monthly rainfall.

The gridded data of rainfall and soil moisture was obtained from Indian Meteorology Department (IMD) and Climate Prediction Centre (CPC). IMD rainfall data is based on rain gauge measurements and are of 0.5 degree spatial resolution, while CPC dataset for rainfall is based on both raingauges and altimetry. The data on cyclones that hit the eastern coast of India was also obtained from IMD, for the period 1963 to 2013.

### III. ANALYSIS

#### A. KHARIF YIELD AND RAINFALL

The annual average Kharif rice yield from 1966 to 2011 is shown in Fig. 2. Till late 1970s, the yield of rice all over India was steady about 900 kg/ha (y-intercept of the trend line). Beyond 1970s, the spurt of green revolution resulted in steady increase in the yield, which is of the order of 28.21 kg/ha per year (slope of the trend line), i.e., an increase of the total rice yield every year at the rate of 3%. This increase in productivity is attributed to the introduction of genetically-modified varieties of seeds, improved agricultural practices and agricultural techniques.

In order to study the relation between the crop yield and rainfall, the trend is removed as in Fig. 3. It is then superimposed with the Summer monsoon rainfall data. The correlation between the two is obtained as 0.69, which proves that a good Summer rainfall is associated with better rice production in the country. A more-detailed analysis is inevitable to understand the spatial dependence and temporal variability in the relation between Kharif rice production and precipitation.

##### 1) Monthly Rainfall contribution to Kharif yield:

The contribution of rainfall for each month of monsoon rainfall to the rice production in summer is determined. It is expressed in terms of the correlation between the rainfall data of each month and the gross yield in summer (Fig. 4). It is clear that the precipitation in July makes high correlation of 0.65 with the kharif yield compared to any other months of the season. Besides, from Fig. 6, it is evident that the average monthly rainfall is also the highest in July (280 mm), followed by August (260 mm). But the correlation for the month of August as obtained from Fig. 4 is mediocre. As a result, the heavy dependence of the kharif crops on the rainfall of July is strongly established. Hence it is inferred that the rainfall in the month of July is quite influential in yield of the kharif crop and a good rainfall in the month of July would yield a better productivity, than rainfall in the other months of the season.

##### 2) Regional crop dependence to Rainfall:

To study how the kharif rice yield varies across India with precipitation, the whole country is divided into four - North East, North West, Central India and Southern Peninsula. The total kharif yield of rice from each of these regions are obtained as follows:

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- (a) North – East - 1550 kg/ha
- (b) North – West - 2300 kg/ha
- (c) Central India - 1550 kg/ha
- (d) Southern Peninsula - 2600 kg/ha

The correlation between the kharif rice produced from each of these regions and the summer rainfall received by them (from 1970 to 2010) are obtained (Fig. 5). It is seen that the crop yield from Southern Peninsula ( $CC = 0.85$ ) and Central India ( $CC = 0.7$ ) bear strong correlation with Summer rainfall. Hence, the excessive dependence of these regions to rainfall for better crop yield is unambiguous. Further, the North-East gives a negative correlation of  $-0.3$ , which may be attributed to the reliance on the irrigation facilities across major rivers like Ganga, Brahmaputra etc.

**B. RABI YIELD AND RAINFALL**

The annual average Rabi rice yield from 1966 to 2011 is shown in Fig. 7. As in case of Kharif rice, Rabi too exhibits a steady proliferation of the order of  $39.39$  kg/ha per year (slope of the trend line), since 1970s. The trend is removed (Fig. 8) and superposed with the post-monsoon rainfall data. A weak correlation of  $0.2$  is obtained between the two.

*1) Monthly Rainfall contribution to Rabi yield:*

The contribution of the post-monsoon rainfall to yearly rabi rice production is studied. The correlations between the monthly rainfall during post-monsoon season and gross yearly Rabi production with Lag-0 and Lag-1 is shown in Fig. 9. The correlations are found to be low generally, although some specific trends of dependencies could be observed. The monthly correlations with Lag-0 does not throw light on any significant tendencies. But, Lag-1 correlations reveal that the precipitation in the month of December has a definite influence on the Rabi rice yield relatively. In short, the Rabi production for a year has a finite dependence on the winter rainfall in the month of December of the previous year.

*2) Rabi yield and cyclones:*

Cyclones are common phenomena during the pre-monsoonal and post-monsoonal period in Bay of Bengal. The states on the eastern coast of India are badly ravaged by cyclones every year. They cause torrential rain and are destructive in nature. The correlations between the number of cyclones that hit the coasts of India and the annual yield of Rabi rice for the regions of Andhra Pradesh, Odisha, Tamil Nadu and West Bengal is shown in Fig. 10. While correlations get hardly established for the regions of Andhra Pradesh and Tamil Nadu, Odisha gives a good positive correlation of  $0.6$ . On the other hand, the region of West Bengal gives negative correlation. Hence, it shows that Odisha reaps some benefits in its Rabi rice production from cyclonic precipitation. But cyclones have an adverse impact on the same in West Bengal.

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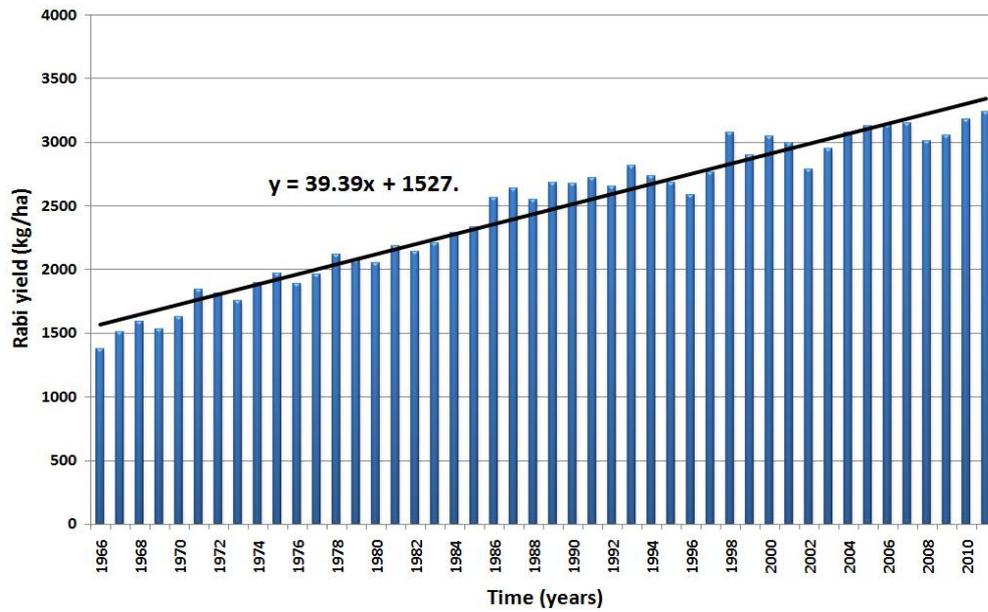


Fig. 7. Total Rabi Rice yield from 1966 to 2011. The trend line (black) shows the steady increase in yield over time.

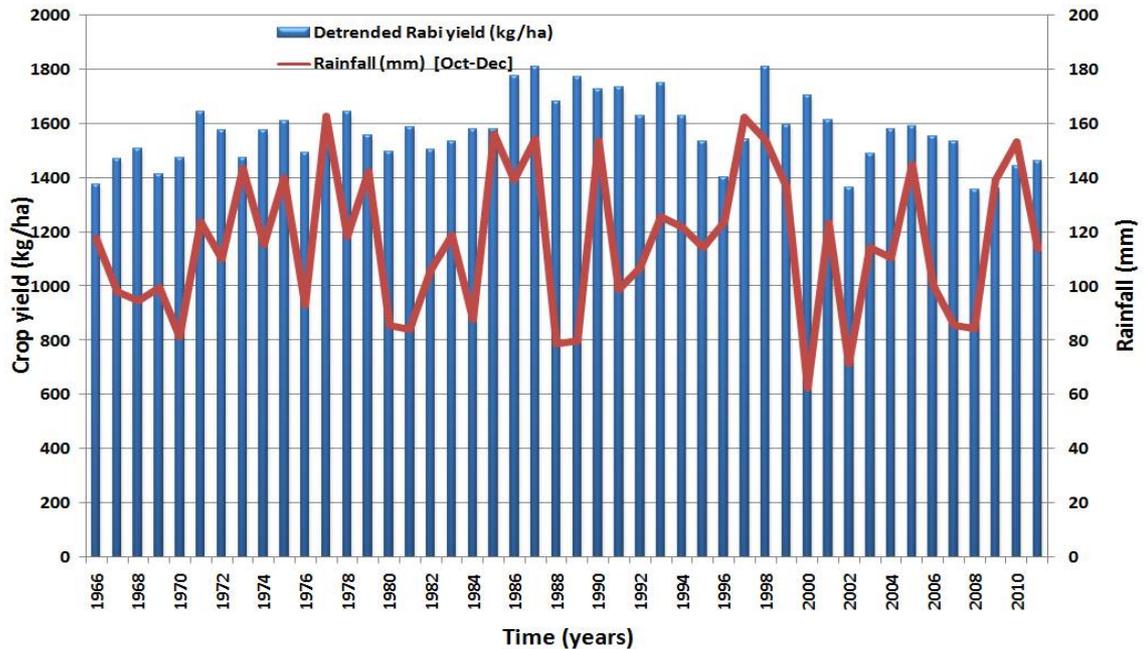


Fig. 8. The detrended Rabi Rice yield and annual rainfall

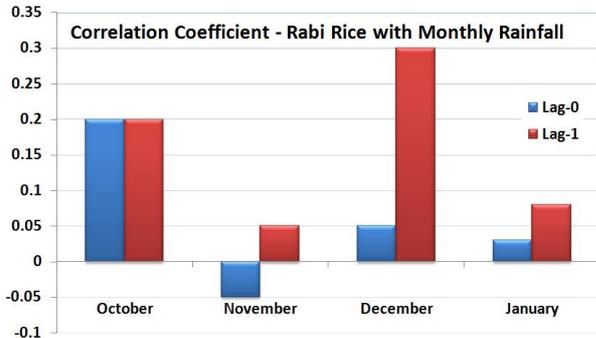


Fig. 9. The correlations between Rabi rice yield and of cyclones monthly post-monsoon rainfall.

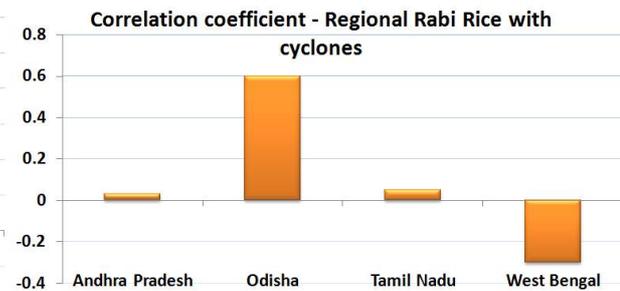


Fig. 10. The correlations between the number and Rabi rice produced in different regions.

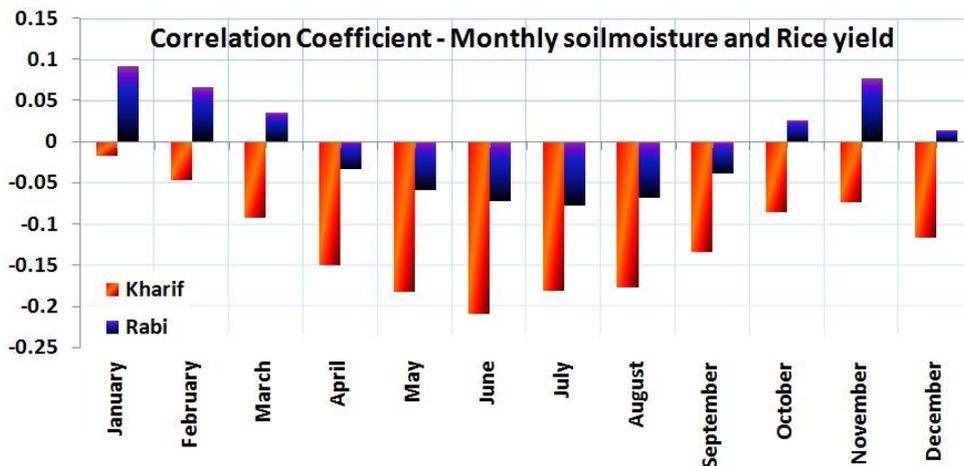


Fig. 11. The correlations between monthly soil moisture and Rabi rice yield for Tamil Nadu

### 3) Rabi Yield and soil moisture

Rice is a crop which depends majorly on soil moisture. To this end, the correlations between the average monthly soil moisture data and gross annual yield of Kharif and Rabi rice for Tamil Nadu are obtained (Fig. 11). Here, Kharif rice yield bears negative correlation with soil moisture of all the months of the year. This is because the soil moisture declines during Summer as parts of Tamil Nadu lies in the rain-shadow region of Western Ghats during summer monsoon. But the kharif crops produced during this period thrive on irrigation. On the other hand, the correlations with Rabi yield is positive in winter but negative in summer. Hence, there is significant dependence of Rabi crop yield on soil moisture during winter.

## IV. CONCLUSION

Indian Monsoon has a major bearing on annual rice production spatially and temporally. This study involves the quantification of the rate of the steady increase in rice production in the country. The dependencies of kharif rice on South-West monsoon rainfall and rabi rice on soil moisture is firmly established. Kharif rice yield correlates better with the precipitation in the month of July. Besides, Southern Peninsula and Central India rely heavily on summer monsoon. On the other hand, Rabi rice yield has a definitive bearing on the December rainfall of the previous year. Further, the Rabi yield of Odisha benefits from cyclonic precipitation, while that of West Bengal suffers serious setback from cyclones.

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