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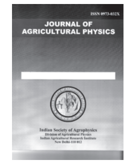

Research Article

South West Monsoon and Food Grain Production of India

JOYDEEP MUKHERJEE[1]*, D.K. DAS[1], V.K. SEHGAL[1], ANANTA VASHISTH[1], RAVENDER SINGH[1] AND S.K. BARARI[2]

[1]*Division of Agricultural Physics, Indian Agricultural Research Institute, New Delhi-110012*

[2]*Division of Livestock and Fisheries Management, ICAR RCER, ICAR Parisar, BV College, Patna-800014, Bihar*

ABSTRACT

Impact of climate on agricultural production is directly linked to food security. Empirical studies through parametric approach have been done focusing on 'mean' of variables, although few studies have dealt with climate impacts in general settings. We characterized the impacts on crop production through a simple statistical approach. Recent studies indicate that monsoon rainfall in India becomes less frequent, but more intense during the latter half of the 20th Century, thus increasing the risk of damage by droughts and floods to *kharif* crops. Historical data (1953-54 to 2010-11) on crops (rice, wheat, coarse cereals, pulses and total food grain) and monthly rainfall (June to September) were analyzed. Normalized yield and production deviations were computed and related to rainfall variables. Both of these show an increasing trend over time. Among the crops, yield of rice has the highest positive correlation (R^2 = 0.60) with total monsoon rain followed by yields of total food grains (R^2 = 0.41) and cereals (R^2 = 0.40), pulses (R^2 = 0.40), wheat (R^2 = 0.36) and coarse cereals (R^2 = 0.28). Impact of rainfall on rice production is significant with R^2 = 0.56. Total cereals and food grains, pulses, coarse cereal productions also shows positive correlations with R^2 ranging from 0.42 to 0.54.

Key words: Rice, Wheat, Pulses, Production, Rainfall

Introduction

India accounts for 2.4% of world's geographical area and 4% of its water resources, but supports about 17% of human population and 15% of the livestock. Agriculture accounts for 14% of national GDP and half of its population still depends on agriculture as the principal source of income (Commission for Agricultural Costs and Prices 2010).

High yielding varieties and improved agricultural inputs expanded greatly in India following the *green revolution*. However, these impacts of country's food grains production could be masked by the negative effect of changes in the monsoon pattern. The all-India means of June-September rainfall during 1961-98 was about 5% less than the mean of previous 30-yr period (Ramanathan *et al*., 2005). This reduction was more than double of the reduction since late 1800s (Dash *et al*., 2007), suggesting further weakening of the monsoon. During the period of 1951-2000, the frequency of heavy and very heavy rain-events in central India increased by 50 and >100%, respectively, while the frequency of moderate events decreased by ~10% (Goswami *et al*., 2006; Mukherjee *et al*., 2005). For the country as a whole, the frequency of occurrence of low to

*Corresponding author,
Email: mjoydeep2k@yahoo.com

moderate rainfall decreased significantly during 1951–2004, while the frequency of long spells decreased, and the frequency of short rainy spells, dry spells, and prolonged dry spells increased (Dash *et al.*, 2009).These changes raise concerns on food security. Many studies have demonstrated that the *kharif* production is low when monsoon rainfall is low (Krishna Kumar *et al*., 2004, Mallick *et al.*, 2007). A drought during 2009 was one of the most severe in current times, with rice harvest declining by 14% (Commission for Agricultural Costs and Prices 2010).

The study employs a statistical approach to analyze the effect of variation in monsoonal rainfall (June to September) since 1953, across productivity and production of food grains. This approach facilitates a thorough analysis of the impact of rainfall across the production distribution. The mean-based regression strategies provide an estimate of the effect of explanatory variables mainly on the mean of a dependent variable, implicitly assuming that the variable follows some parametric form of distributions such as normality. However, in the context of studying climate impacts on agricultural yield, it is appropriate to analyze the changes in temperature and precipitation across the conditional distribution of yields under more general settings.

Materials and Methods

Data

Historical data (1953-54 to 2010-11) on crops (rice, wheat, coarse cereals, pulses and total food grains) were obtained from the Handbook of Statistics on the Indian Economy. Data were examined for any steep-change discontinuities indicative of a significant shift in recording method. Preliminary analyses showed linear positive trends of increasing yields over time. The yields of both crop seasons are reported in one financial year starting from March and ending in April of the subsequent year. For simplicity, we took the yield in a given financial year under the second calendar year. For example, rice yield in 1953-54 is counted as the yield for the year 1954. To delineate technology trend from the data, statistical trend analysis and normalized deviation has been carried out. All India rainfall data (monthly) were analyzed for the study. Historical data (1953 to 2010) for the month of June to September were used for the study.

Statistical analysis

For trend analysis, the reference year was taken as 1953 and the subsequent years were referred to as modified years (Tm), where Tm = (Year – 1953) for 1953-54 crop season. The scatter plot of yield (or production) vs. year (Tm) was examined to find out presence or absence of trend for the entire period or part thereof. The result was categorized into three scenarios as no trend, single trend and two trends.

Highly varying component of yield and production time series appeared as transients around the trend line. The yield or production (from average or trend equation) for a given year was normalized with respect to predicted yield to take care of proportionate inter-annual fluctuations. Correlations of normalized deviations with rainfall data were worked out to realize the final model (Patil *et al*., 1996).

Based on these predicted values, normalized deviations of yields for each year were computed as per the following expression:

$$\Delta Y_i = Y_{ti} - Y_{oi} \quad \ldots(1)$$

$$NDY_i = - \Delta Y_i / Y_{ti} = - (Y_{ti} - Y_{oi})/ Y_{ti}$$

Where,

ΔYi = Absolute yield or production deviation for the i^{th} year

Y_{ti} = Trend-predicted yield or production from trend or average for the i^{th} year

Y_{oi} = Observed yield or production for the i^{th} year

NDY_i = Normalized yield deviation for i^{th} year, with respect to long-term average

In case of two trends situation, the calculated NDY using the average yield of initial phase and the trend equation for the later phase were combined at cross-over year (m). Cross-over year

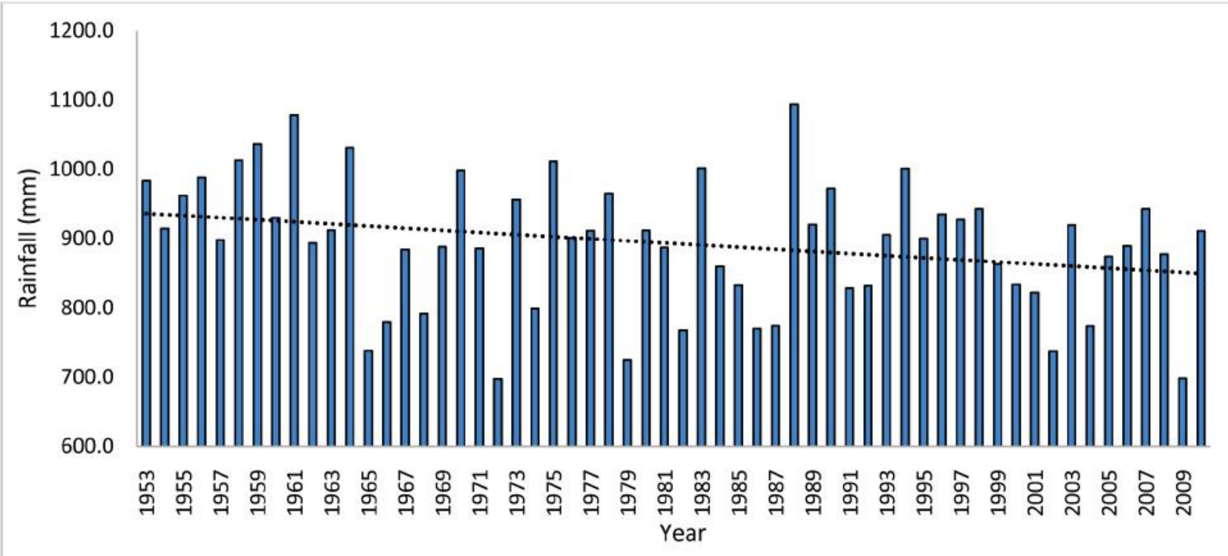

Fig. 1. Total rainfall during south-west monsoon (June-September) over the period (1953-2009)

was the year at which NDY calculated for the two phases was closest in magnitude. Thus the final NDY of whole series consisted of NDY calculated using Y_{ti} from average value up to a year before the cross-over year, and the same calculated using Y_{ti} from trend equation from cross-over year onwards.

Results and Discussion

Monsoonal rainfall pattern

Over the years, the total rainfall due to south west monsoon decreased (Fig. 1). The average S-W monsoonal rainfall is 892.8 mm. Rain in the month of June is showing increasing trend but for other months, the trends are decreasing. Recent studies indicate that the total rainfall during monsoon (June-September) becomes less, but the extreme rainfall events increased (Ramanathan *et al*. 2005; Goswami *et al*., 2006; Dash *et al*. 2007; Ramesh and Goswami 2007; Dash *et al*., 2009).

Crop yield and production

Crop yields and production show an increasing trend over time (Fig. 2 and 3). Over time, technology and crop management techniques have increased crop production. The increase in production and yield has been over 100% for rice, wheat, coarse cereals and pulses, and the trend is consistent. However, yields have apparently become more variable over the years. For both climate variables and crop yield & production variables, analysis of correlations shows positive trend. No negative correlation is present to affect the results.

Positive relationships are observed between rains and crop yields (Table 1). Correlation is better with total rainfall (June-September) than rain in individual month (June, July, August and September). Rice yield shows the highest positive correlation (R^2 = 0.60) with total monsoonal rainfall (June to September) followed by total food grain (R^2 = 0.41) and cereals (R^2 = 0.40), pulses (R^2 = 0.40), wheat (r^2 = 0.36) and coarse cereals (R^2 = 0.28) (Fig. 4). Among the months, month's rainfall during September has the highest effect on crop yields. Rice yield is more correlated with July rainfall than other months as *kharif* rice transplanting is associated with July rainfall. Crop yield (normalized deviation) is less correlated with June rainfall as it has high variability. The effect of monsoonal rainfall on wheat is also positive. Although it is a *rabi* season crop and grown mostly with assured irrigation, when monsoonal rainfall is better, soil profile moisture recharge becomes more. Hence, requirement of irrigation might be less during *rabi*.

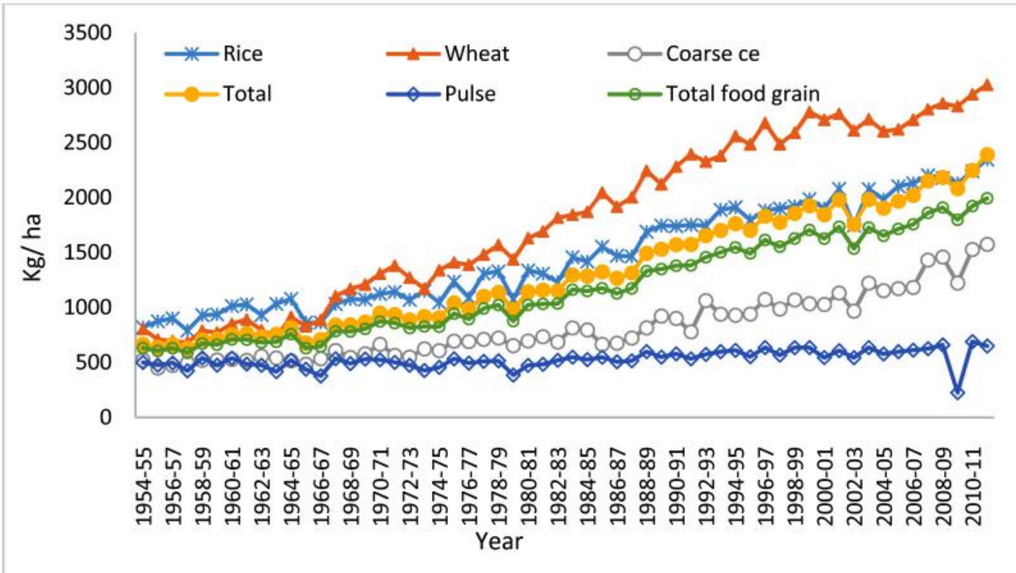

Fig. 2. Trends in crop yields in India over the years

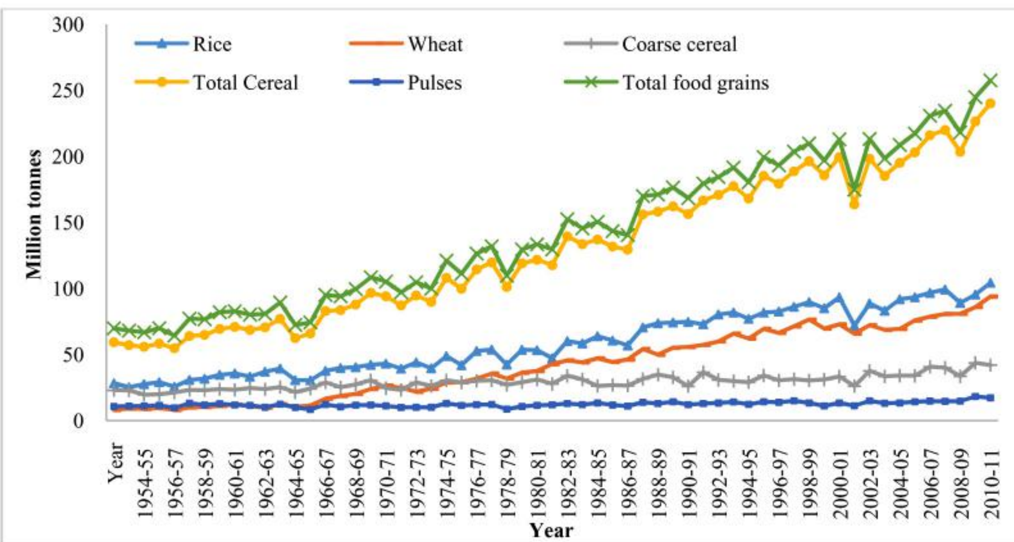

Fig. 3. Trends in crop production of India over the period (1954-55 to 2010-11)

Table 1. Correlation coefficient (R^2) of yields and monthly rainfall

	Rainfall				
	June	July	August	September	Total
Rice	0.190	0.363	0.158	0.341	0.603
Wheat	0.131	0.143	0.159	0.155	0.362
Coarse cereal	0.0004	0.112	0.134	0.263	0.278
Total cereals	0.022	0.168	0.160	0.323	0.399
Pulses	0.015	0.169	0.179	0.317	0.397
Food grains	0.040	0.194	0.155	0.284	0.412

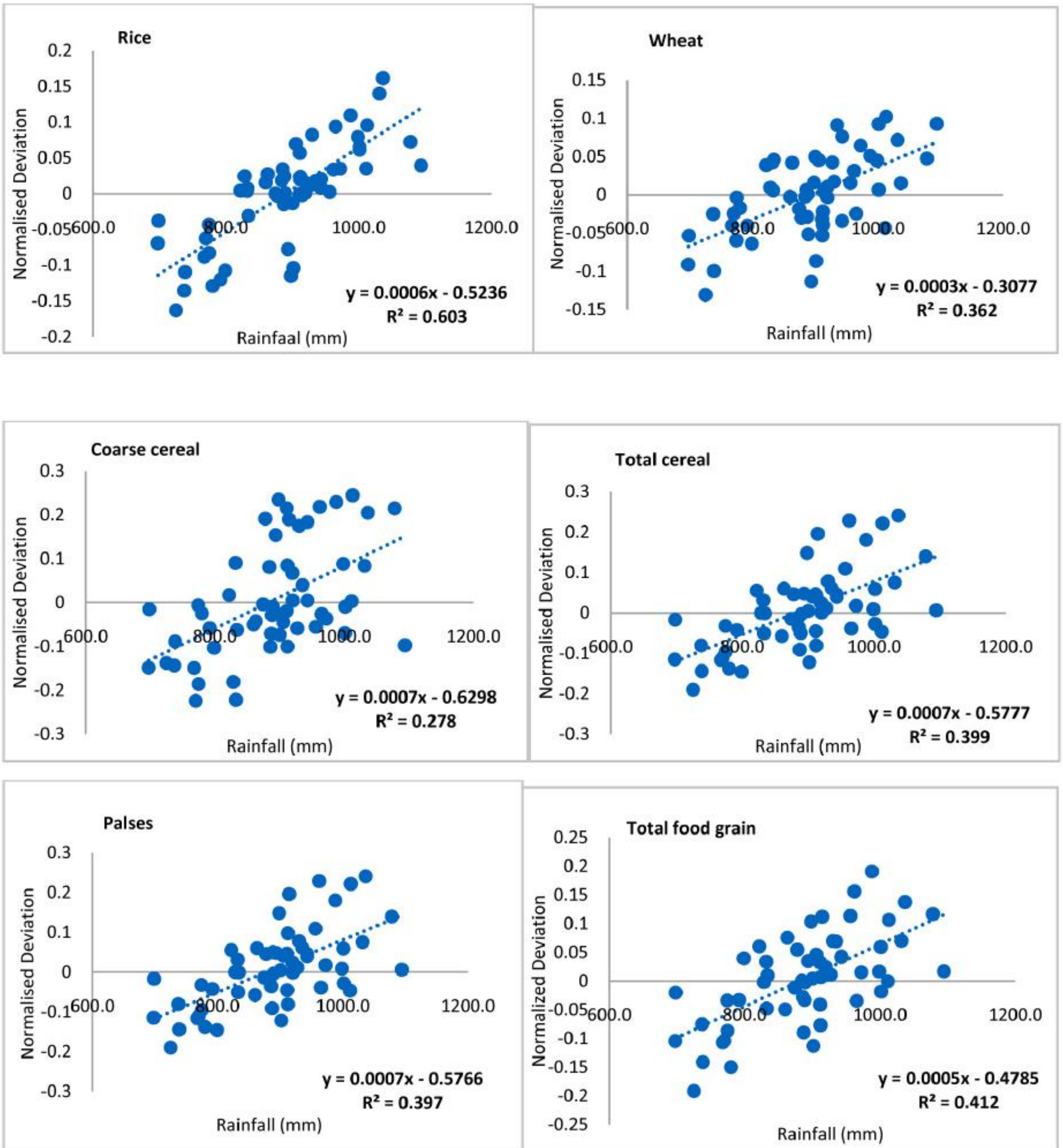

Fig. 4. Correlation with crop yield (normalized deviation) and total monsoon rainfall (June to September)

Crop production

Total monsoonal rainfall is highly correlated with crop production. Rainfall influences more on rice followed by total cereals and food grains, coarse cereals and pulses (Table 2). Monsoonal rainfall affect the total rice production of the country with positive correlation (R^2 = 0.56). Total cereals, food grain, pulses and coarse cereal productions also show positive correlations with R^2 ranging from 0.42 to 0.54. Similar trends (like yield-rainfall) are observed when production (normalized deviation) is correlated with individual month rainfall (Fig. 5). The month of September shows the highest correlation (R^2=0.17 to 0.30) followed by July (R^2=0.18 to 0.31), August (R^2=0.14 to 0.24) and June (R^2=0.05 to 0.21).

Table 2. Correlation coefficient (R^2) of production and monthly rainfall

	Rainfall				
	Total (Jun-Sept)	June	July	August	September
Rice	0.559	0.183	0.267	0.174	0.290
Wheat	0.418	0.140	0.182	0.236	0.173
Coarse cereal	0.429	0.053	0.181	0.227	0.279
Total cereal	0.524	0.206	0.288	0.152	0.266
Pulses	0.459	0.059	0.280	0.144	0.338
Food grains	0.540	0.173	0.311	0.166	0.296

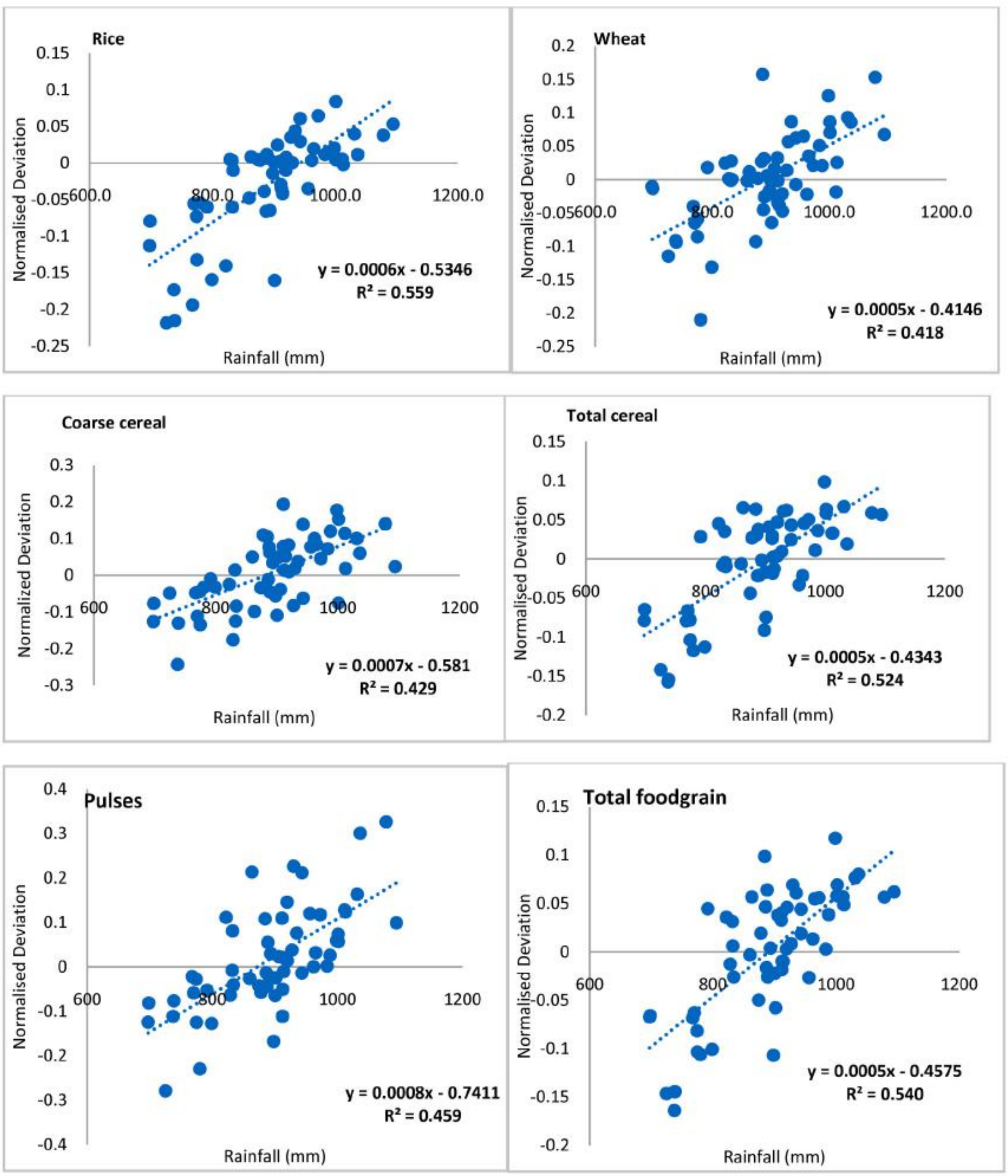

Fig. 5. Correlation with crop production (normalized difference) and total monsoon rainfall (June to September)

Conclusions

The correlation in this study is based on a combination of both agricultural and meteorological data, which were analyzed at the country level. We observed that total monsoon rains (June-September) is highly correlated with crop yield and production.

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