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Short Communication

Rainfall variability and its effect on *kharif* rice yield in Manipur: a multi-decadal analysis

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Rice is the staple food in India's north-eastern states, notably Manipur, primarily cultivated during the southwest monsoon season as a *kharif* crop. Its growth heavily depends on rainfall for moisture, and previous research has shown the impact of rainfall variability on rice yield. Karmokar *et al.,* (2020) investigated the influence of seasonal climatic variability on rice yield and observed a positive correlation between rainfall and rice yields across various regions of monsoon Bangladesh. Singh *et al.,* (2015) found a significant rice yield gap in eastern and north-eastern India due to inadequate management practices, including irrigation infrastructure deficiencies. They suggested that improving these practices could increase rice yield by 11 to 22 per cent in the studied districts. On the other hand, Chakraborty *et al.,* (2017) analysed rainfall data from various meteorological stations across the region, revealing a clear shift over time in the time series of rainfall data.

Though numerous studies have investigated the influence of rainfall variability on *kharif* rice yield in India, limited attention has been given to the topic in Manipur. This gap is significant considering the inadequate irrigation infrastructure in Manipur and the observed increase in rainfall variability. Evaluating the sensitivity of rice yield to such fluctuations is crucial for effective agricultural planning. Therefore, this study examines the impact of rainfall variations during the southwest monsoon (SWM) months on rice yield in Manipur from 1980 to 2020.

The analysis utilised the Indian Meteorological Department's (IMD) 0.25 x 0.25-degree gridded rainfall data alongside rice yield data from official statistical handbooks. To examine historical rainfall changes the Rainfall Anomaly Index (RAI) was calculated by subtracting the mean from the actual rainfall value (X) and dividing the result by the standard deviation (σ).

A log-linear model was employed for yield sensitivity analysis, with rainfall in SWM months as the independent variables and rice yield as the dependent variable. The model is as follows:

$$\log y = \beta 0 + \beta 1 \log x1 + \beta 2 \log x2 + \beta 3 \log x3 + \beta 4 \log x4 + \varepsilon$$

where y = *Kharif* yield of rice (t ha^{-1}), x1= June rainfall (mm), x2 = July rainfall (mm), x3 =August rainfall (mm), x4 =September rainfall (mm), ε = error term.

This model was selected for two reasons: Firstly, it is robust enough to yield variations stemming from non-climatic factors, eliminating the need for detrending. Secondly, it offers a straightforward interpretation of slope coefficients, reflecting the percentage changes in the dependent variable associated with a 1% change in the independent variable. These data and techniques were found to be highly effective for assessing *kharif* rice yield sensitivity to rainfall, therefore, were recommended by Dkhar *et al.,* (2017).

Before yield sensitivity is analysed, it is important to understand the rainfall characteristics of the region. Hence, the annual and seasonal variation in mean rainfall and trend coefficients for the state of Manipur are given in Table 1. The registered annual rainfall value for the study period is 1559.42 mm followed by monsoon (959.4 mm), pre-monsoon (425.5 mm) and post-monsoon (164.4mm). It is quite clear from the table that rainfall extremes have fluctuated in both annual and seasonal levels. Variations in monsoon rainfall are likely the primary contributing factor to fluctuations in annual rainfall from 926.7 mm to 2314.8 mm, as it constitutes the most significant portion of the total annual rainfall. Monsoon season also has the minimum variability (CV=19.9%) relative to pre-monsoon (CV=29.5%) and post monsoon (CV= 53.1%).

Monsoon rainfall has fluctuated both above and below across its long term mean as shown in the Fig. 1**.** It is worth noting that years falling within the ±1 standard deviation (SD) bands of Rainfall Anomaly Index (RAI) values represent periods of sig-

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Table 1: Seasonal and annual rainfall in Manipur during 1980-2022.

Season	Normal rainfall(mm)	Percentage contribution	Extreme value (total monthly) (mm)		Trend coefficient
			Minimum	Maximum	
Pre-monsoon	425.5	27.4	203.7	732.9	-2.72
Monsoon	959.4	61.9	610.3	1518.4	-3.73*
Post-monsoon	164.4	10.6	10.8	395.0	1.25
Annual	1549.4	-	926.7 (Year 2001)	2314.8 (Year 1991)	-7.70*

* represents significance at 5% level

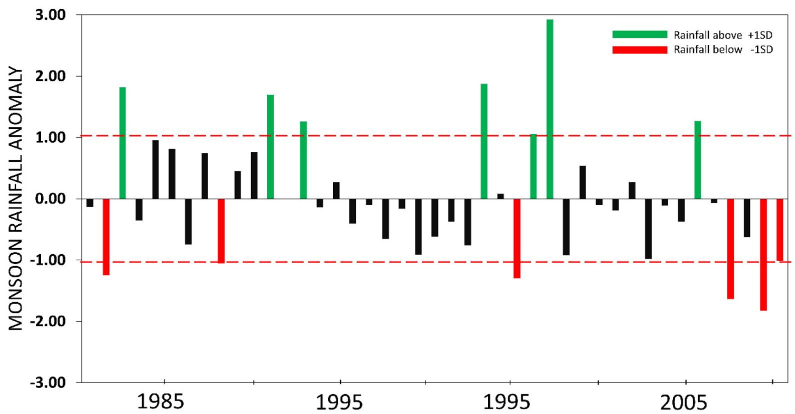

Fig. 1: Monsoon rainfall variations across long term means obtained using RAI.

Table 2: Descriptive statistics for the variables used in the regression model

Variables	Mean	Maximum	Minimum	CV %
Dependent variable				
Yield (t ha^{-1})	2.21	2.98	1.47	17.0
Explanatory variables				
June rainfall (mm)	252.6	480.1	123.2	33.7
July rainfall (mm)	276.7	513.2	124.4	31.9
August rainfall (mm)	242.0	491.0	101.2	31.0
September rainfall(mm)	188.0	364.8	13.1	40.6

nificant surplus or deficit. The frequency of surplus years (N=7) is nearly equal to the frequency of deficient years (N=6). However, three out of the six years with deficient rainfall have occurred in the past five years, indicating an increase in the frequency of deficit rainfall events.

According to the descriptive data presented in the Table 2, the state's *kharif* rice yield exhibit variations ranging 1.47 t ha^{-1} to 2.28 t ha^{-1} with an average yield of 2.21 t ha^{-1}. Similarly, rainfall in the critical monsoon months also display fluctuations with varying mean, minimum, maximum and CV figures. The average monthly rainfalls were 252.6, 277.7, 242.0 and 188.0 mm in June, July, August and September, respectively, taken as explanatory variables from 1980–2022. The variation in yield (dependent) was 17.0%, and the variations in the June, July, August and September rainfall were 33.7, 31.9, 31.0 and 40.6%, respectively (Table 2).

Table 3 presents the regression output along with the calculated coefficients. It is apparent from the table that rainfall in the month of June, August and September has a positive and significant influence on rice yield, whereas July rainfall has negative and insignificant impact (α=5 %). The model outputs indicate that a 1% increase in June rainfall has led to a 0.08% increase in the yield of *kharif* rice. This relationship is attributed to the significant influence of rainfall during the sowing period on rice yield. Similarly, for August, the corresponding figure is 0.04%, and a similar value was also observed for rainfall in September. Adequate and timely June rainfall is essential for proper germination, transplanting, and early growth stages of the rice crop; August rains help rice in the crucial reproduction stage of its crop cycle (Bal *et al.*, 2023). As shown above, the sensitivity of rice yield to June and August rainfall is critical due to the declining trend in monsoon rainfall observed in the region (Saha and Ghosh, 2019). This trend could have significant implications for future yield, especially considering the uncertainties associated with monsoon rains under climate change.

Table 3: Effect of rainfall on rice yield: log-linear model

Variable	β-coefficient	Standard error (SE)	*p* value
Intercept	-10.47	1.26	0.001
June rainfall (mm)	0.08	0.04	0.09*
July rainfall (mm)	-0.07	0.05	0.11
August rainfall (mm)	0.04	0.05	0.07*
September rainfall (mm)	0.04	0.03	0.02*
Time	0.005	0.00	0.001*
R-square	0.70		0.001
Adjusted *R*-square	0.66		0.001

* represents significance at 5% level

Thus, the *kharif* rice yield in the state is sensitive to rainfall variations during monsoon months, with varying degrees and effects. While June and August rainfall significantly impacts rice yield, July rainfall shows a negative effect, although statistically insignificant. The observed declining trend in monsoon rainfall, coupled with uncertainties surrounding climate change and its potential impact on future monsoon patterns, underscores the importance of adopting crop management systems to improve resource use efficiency and address existing constraints. These measures are essential for sustaining and increasing rice yield in changing climatic conditions.

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Data availability: The IMD gridded rainfall data can be downloaded from its website (https://www.imdpune.gov.in/cmpg/Griddata/Rainfall_25_NetCDF.html), while crop data can be obtained from the author upon reasonable request.

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