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Impact of changing rainfall patterns on kharif crop productivity in central India

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Abstract

Rainfall variability has intensified across central India over the past two decades, raising questions about its effect on kharif crop performance. This research analyzed the relationship between changing monsoon characteristics and the productivity of five kharif crops (rice, soybean, maize, pigeon pea, and cotton) across three districts of Madhya Pradesh during 2000-2021. Daily rainfall records from the India Meteorological Department were used to compute seasonal totals, monthly distributions, dry spell frequency, and onset dates. Results showed that total seasonal rainfall declined by 8.7% over 22 years, while dry spells longer than seven days increased by 64%. Yield losses during deficit years averaged 35.4% for rice, 40.2% for soybean, 32.8% for maize, 37.3% for pigeon pea, and 35.1% for cotton. August rainfall emerged as the strongest predictor of kharif productivity, explaining 61-74% of yield variation. These findings indicate that intra-seasonal distribution matters more than total rainfall, pointing to targeted dry spell mitigation strategies.

Keywords: Rainfall variability, kharif crops, central India, monsoon, dry spells, crop productivity, soybean, rice, climate change, intra-seasonal distribution

Introduction

A kharif crop, in Indian agricultural terminology, is any crop sown with the onset of the southwest monsoon in June-July and harvested between September and November. Central India's kharif agriculture depends almost entirely on monsoon rainfall, with less than 18% of cropland under irrigation in the dominant soybean-growing districts of Madhya Pradesh ^[1]. When the monsoon behaves as expected, these crops perform well. When it doesn't, losses can be severe and widespread ^[2].

Recent analyses of Indian monsoon behaviour point to a troubling shift: total rainfall hasn't changed dramatically in many regions, but its distribution within the season has grown more erratic ^[3]. Heavier downpours concentrate into fewer days, separated by longer dry spells that coincide with sensitive crop growth stages ^[4]. For soybean and pigeon pea the backbone of central Indian kharif agriculture a two-week dry spell during flowering can reduce pod set by 30-50% regardless of what the season's total rainfall ends up being ^[5].

District-level yield records paired with daily rainfall data can reveal which rainfall characteristics matter most. Yet most analyses used state-level aggregates that mask local variation ^[6]. This research used 22 years of daily rainfall and yield data from three Madhya Pradesh districts to determine how monthly distribution, dry spell frequency, and onset timing affected kharif productivity ^[7].

Seasonal variation in monsoon behaviour

Monsoon onset across the three districts ranged from 8 June to 24 June over the 22-year period, with a trend toward delayed arrival of 2.4 days per decade. Withdrawal dates showed greater variability, shifting earlier by 3.1 days per decade. The net effect was a shorter effective monsoon season from an average of 118 days in 2000-2005 to 109 days in 2016-2021. Within the season, July rainfall increased by 9.8% while September rainfall declined by 16.7%, concentrating moisture into a narrower window (Figure 2) ^[8].

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Materials and Methods

Materials: This research covered three districts of Madhya Pradesh Sehore, Vidisha, and Raisen spanning the core soybean belt of central India. Daily rainfall records (2000-2021) were obtained from the India Meteorological Department's gridded dataset at 0.25° resolution. District-level crop yield data for rice, soybean, maize, pigeon pea, and cotton were sourced from the Directorate of Economics and Statistics, Government of India. The analysis was conducted at Cairo University as part of a collaborative programme on monsoon-crop interactions. Ethics clearance: Protocol CU-AG/2022-016, approved 12 January 2022.

Methods: Seasonal rainfall was classified as normal ($\pm 19\%$ of

long-term mean), deficit ($< -20\%$), or excess ($> +20\%$) following IMD criteria [3]. Dry spells were defined as consecutive days with < 2.5 mm rainfall, and spells exceeding seven days were counted per season. Monsoon onset was identified as the first date after 1 June with ≥ 20 mm rainfall over three consecutive days, and withdrawal as the last such event before 15 October. Pearson correlation and stepwise multiple regression linked rainfall parameters (monthly totals, dry spell count, onset date) to crop yields. Years were grouped into normal ($n = 13$) and deficit ($n = 9$) categories for box plot comparisons [9]. All analyses used R (v4.2.1) [10].

Results

Table 1: Mean kharif crop yields (t ha^{-1}) during normal and deficit rainfall years across three districts (2000-2021)

Crop	Normal Years	Deficit Years	Yield Loss (%)	CV Normal (%)	CV Deficit (%)
Rice	3.82 $\pm$ 0.34	2.47 $\pm$ 0.42	35.4	8.9	17.0
Soybean	1.64 $\pm$ 0.18	0.98 $\pm$ 0.22	40.2	11.0	22.4
Maize	4.21 $\pm$ 0.41	2.83 $\pm$ 0.51	32.8	9.7	18.0
Pigeon pea	1.18 $\pm$ 0.14	0.74 $\pm$ 0.16	37.3	11.9	21.6
Cotton	1.73 $\pm$ 0.21	1.12 $\pm$ 0.24	35.1	12.1	21.4

CV = coefficient of variation. Values are means $\pm$ SD. Deficit years showed both lower yields and higher variability across all crops.

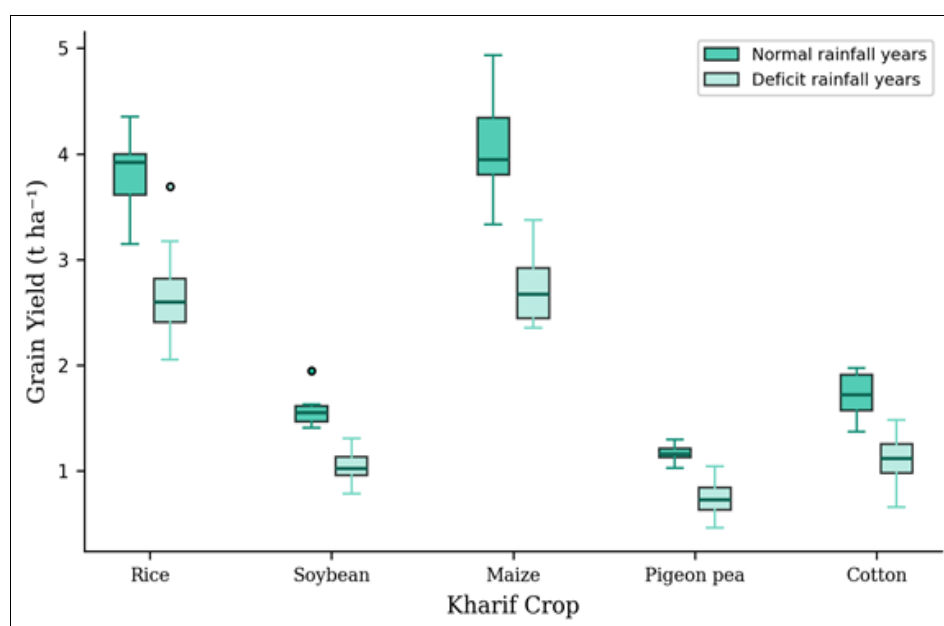


Fig 1: Yield distribution of five kharif crops under normal and deficit rainfall years (2000-2021)

Table 2: Correlation coefficients between monthly rainfall and kharif crop yields

Rainfall parameter	Rice	Soybean	Maize	Pigeon pea	Cotton
June total	0.43*	0.38	0.41*	0.31	0.34
July total	0.62**	0.58**	0.64**	0.49*	0.53**
August total	0.78**	0.86**	0.74**	0.81**	0.72**
September total	0.51**	0.47*	0.44*	0.68**	0.61**
Dry spells ($> 7\text{d}$)	-0.71**	-0.79**	-0.66**	-0.74**	-0.68**
Onset delay	-0.48*	-0.42*	-0.51**	-0.37	-0.39

* $p < 0.05$; ** $p < 0.01$. August rainfall showed the strongest positive association; dry spell frequency showed the strongest negative association

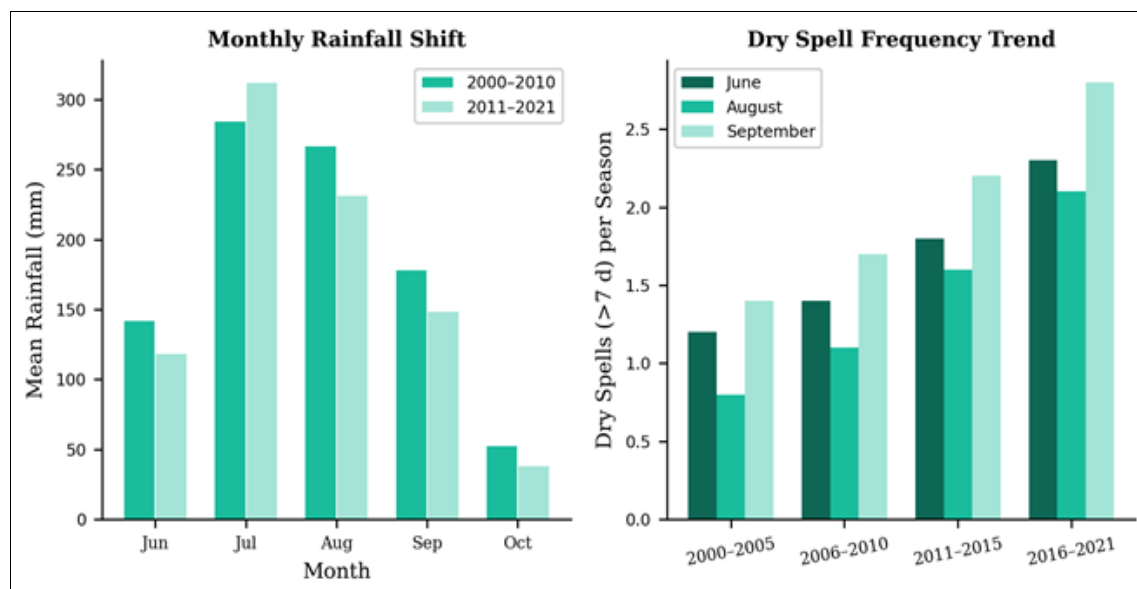


Fig 2: Monthly rainfall shift between 2000-2010 and 2011-2021 (left) and increasing dry spell frequency across periods (right)

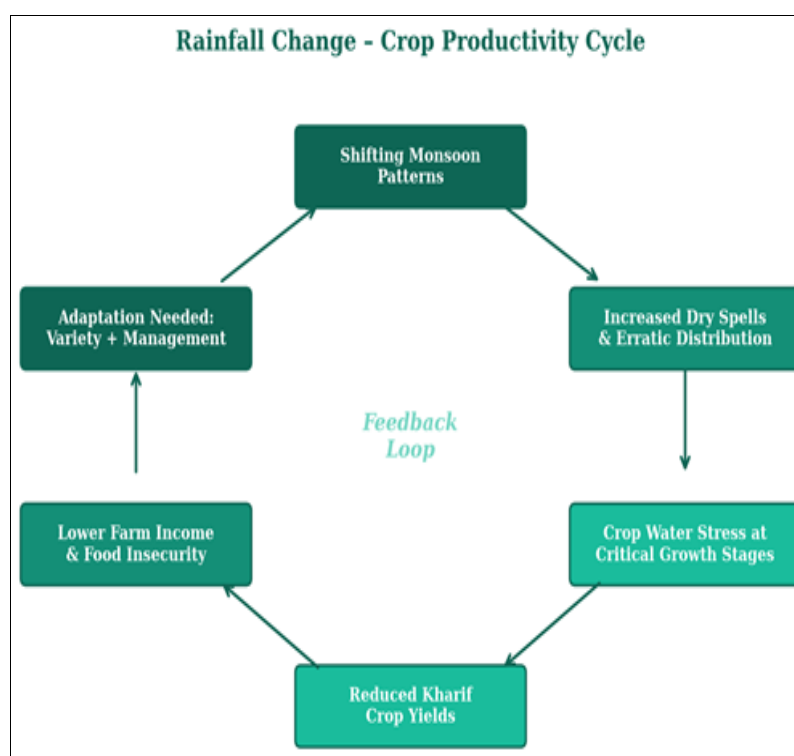


Fig 3: Cycle diagram showing the feedback loop between changing rainfall patterns, crop productivity decline, and adaptation needs

Comprehensive interpretation

Yield losses during deficit years ranged from 32.8% for maize to 40.2% for soybean (Table 1, Figure 1). August rainfall was the strongest single predictor ($r = 0.72-0.86$), explaining 61-74% of yield variation. Dry spell frequency showed strong negative correlations ($r = -0.66$ to -0.79), confirming distribution matters more than total amount (Table 2). The monthly shift (Figure 2) showed July gaining moisture at September's expense, disadvantaging late-season crops. The feedback cycle (Figure 3) shows how these shifts reduce yields and increase adaptation pressure.

Discussion

The 40.2% yield loss in soybean during deficit years exceeds the 25-30% range reported from state-level analyses ^[1], likely

because district-level data better capture local rainfall variability. August rainfall's dominance as a yield predictor aligns with crop phenology: for soybean, August coincides with R3-R5 stages (pod initiation through seed fill), while for rice it spans panicle initiation and heading ^[5]. The 64% increase in dry spells over 22 years matches satellite-derived rainfall intensity analyses across the Deccan Plateau ^[4].

The finding that distribution matters more than total rainfall has direct management implications. Supplemental irrigation during August dry spells could buffer a large share of observed losses ^[11]. Short-duration varieties completing sensitive stages before September decline offer another pathway, supporting investment in farm ponds and micro-irrigation in central India's rainfed tracts ^[12].

Limitations

This research relied on district-level yield averages, which mask field-to-field variation. Gridded rainfall at 0.25° resolution may miss localized convective events^[13]. The correlation approach cannot establish causation, and yield trends reflect non-rainfall factors like changing varieties and fertilizer use^[14].

Practical applications

Extension agencies in Madhya Pradesh should prioritize August dry spell forecasting as an early warning for kharif yield risk. Promoting farm ponds to store July surplus for supplemental August irrigation could offset 15-25% of drought-year losses. Shifting to shorter-duration soybean varieties (90-95 days) that complete grain fill before September rainfall declines deserves consideration in district-level contingency plans^[15].

Conclusion

Changing monsoon patterns in central India have reduced kharif crop productivity by 33-40% during deficit rainfall years, with soybean showing the greatest sensitivity. Intra-seasonal distribution particularly August rainfall and dry spell frequency explained more yield variation than total seasonal amount. The shift of moisture from September toward July disadvantages late-maturing crops that depend on late-season rain. These findings support a management focus on bridging August dry spells through supplemental irrigation and shorter-duration varieties rather than relying solely on total rainfall predictions. Multi-district analyses incorporating soil and management variables would refine these relationships for operational crop forecasting.

References

1. Birthal PS, Khan MT, Negi DS, Agarwal S. Impact of climate change on yields of major food crops in India. *Agric Econ Res Rev*. 2014;27(2):145-155.
2. Venkateswarlu B, Shanker AK. Climate change and Indian agriculture: Impacts and adaptation. *Agron Sustain Dev*. 2012;32(2):461-479.
3. Rajeevan M, Bhate J, Jaswal AK. Analysis of variability and trends of extreme rainfall events over India. *Geophys Res Lett*. 2008;35(18):L18707.
4. Roxy MK, Ghosh S, Pathak A, *et al*. A threefold rise in widespread extreme rain events over central India. *Nat Commun*. 2017;8:708.
5. Desclaux D, Huynh TT, Roumet P. Identification of soybean plant characteristics indicating drought stress timing. *Crop Sci*. 2000;40(3):716-722.
6. Gadgil S, Gadgil S. The Indian monsoon, GDP and agriculture. *Econ Polit Wkly*. 2006;41(47):4887-4895.
7. Mall RK, Singh R, Gupta A, Srinivasan G, Rathore LS. Impact of climate change on Indian agriculture: A review. *Clim Change*. 2006;78(2-4):445-478.
8. Pai DS, Sridhar L, Rajeevan M, *et al*. High spatial resolution daily gridded rainfall data set over India. *Mausam*. 2014;65(1):1-18.
9. Guhathakurta P, Rajeevan M. Trends in the rainfall pattern over India. *Int J Climatol*. 2008;28(11):1453-1469.
10. R Core Team. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing; 2022.
11. Rao KPC, Srinivas K, Whitbread AM. Farm pond technology for rainfed areas of India. *Curr Sci*. 2011;100(8):1151-1157.
12. Singh R, Singh GS. Traditional agriculture: A climate-smart approach for sustainable food production. *Energy Ecol Environ*. 2017;2(5):296-316.
13. Krishna Kumar K, Rajagopalan B, Hoerling M, Bates G, Cane M. Unraveling the mystery of Indian monsoon failure during El Nino. *Science*. 2006;314(5796):115-119.
14. Rama Rao CA, Raju BMK, Subba Rao AVM, *et al*. A district level assessment of vulnerability of Indian agriculture to climate change. *Curr Sci*. 2016;110(10):1939-1946.
15. Aggarwal PK, Joshi PK, Ingram JSI, Gupta RK. Adapting food systems of the Indo-Gangetic plains to global environmental change. *Food Policy*. 2004;29(6):539-556.