Spatial Distribution of Monsoon and Agricultural Production

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This study examines spatial distribution of rainfall and its influence on Kharif crop cultivation in India. By utilizing matched longitudinal data on rainfall and agricultural output at the district level, the study exploits variations in rainfall to assess its impact on crop production. The results underscore the importance of rainfall for all crops; however, extreme weather events – such as excessive or insufficient rainfall – disrupt production processes, leading to crop damage and reduced yield quality. The timing of these extreme weather events is also crucial due to differing crop production cycles. Insufficient rainfall in June and July adversely affects cereal and pulses production, while oilseeds are particularly vulnerable to excessive rainfall during the harvesting period.

Introduction

Rainfall plays a crucial role in the production of *Kharif* crops, mainly because irrigation alone cannot meet the water needs of these crops. Despite decades of research leading to the development of high-yield crop varieties, climate-resilient varieties and cropping technologies, much of the production still relies on rainfall. Climate change has altered weather patterns globally, resulting in extreme conditions such as floods, droughts, and heatwaves in India in recent years. In this context, this study examines the role of rainfall in crop production, particularly focusing on the effects of both excessive and insufficient rainfall.

Agricultural production is vital for the country's economy as the sector is contributing 18.2 per cent to GDP and employing 42.3 per cent of the workforce.[1] Consequently, rainfall influences macroeconomic policies. Fiscal policy is linked to various price support systems and agricultural subsidies, while monetary policy is affected by mechanisms aimed at maintaining price stability, which are influenced by food prices.

In a country like India, with its vast landmass and diverse agroclimatic conditions, crop production varies significantly across regions. Although various policies over time have incentivized farmers to cultivate specific crops, production remains largely influenced by local agroclimatic factors. For instance, crops such as paddy, certain pulses, and oilseeds are primarily grown in areas that receive substantial southwest monsoon rainfall. Else, the production process will be heavily irrigation-dependent that puts pressure on the alternative sources of water (groundwater, reservoirs, *etc.*). This paper uses spatial variation of rainfall across districts and estimate its impact on the production process of different *Kharif* crops. This study also estimates the effects of deficient or excess rainfall in districts cultivating these crops, and how these variations disrupt the production processes. Due to the nature of these crops, it is crucial to recognize that inadequate or excessive rainfall during the sowing or harvesting stages can have differing impacts on final production outcomes. Thus, this study tries to identify the extreme weather events in specific months that may have an impact on the different crops. Given that southwest monsoon rainfall occurs from June to September, we focus on this timeframe and the spatial distribution of rainfall in specific months to evaluate its effects on production.

The remaining part of the article is broadly structured as follows. Section II presents relevant literature on the rainfall-agriculture relationship. Section II examines the stylised facts regarding spatial distribution of rainfall and agricultural production

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[1] https://pib.gov.in/PressReleasePage.aspx?PRID=2034943

in India. While methodology to study the impact of spatial and temporal distribution of rainfall on agricultural production is discussed in Section IV, the empirical results are provided in Section V. Section VI concludes the study.

II. Select Literature

The relationship between rainfall and agriculture in India is widely studied. For brevity, we focus on selected studies that have used granular data to study this topic. Prasanna (2014) found that monsoon rainfall has a direct and positive effect on yields in the *Kharif* season, while post monsoon rainfall affects *Rabi* crops by influencing water and soil moisture. Galle and Kazenberger (2024) used the predictions of the global climate models to estimate the impact of climate change on crop yield and found that, depending on different emission scenarios affecting rainfall and temperature, there could be a 3-22 per cent loss in rice yields between 2021-2100. Focusing on the state of Maharashtra, Zachariah *et al.* (2020) observed that rainfall deficit has a relatively stronger effect on crop production compared to rising temperatures. Ghosh and Kaustubh (2023) noted that that rainfall has a non-linear relationship with inflation mainly through its effects on agricultural GVA. Gupta *et al.* (2023) analysed state-level production and rainfall data to evaluate the importance of south-west monsoon on *Kharif* crops in the context of improvement in irrigation infrastructure and found that irrigation mitigates the impact of deficient rainfall. Other studies that focus on the relationship between rainfall and agricultural crop production include Meher *et al.* (2015); Auffhammer *et al.* (2012); Fishman (2016); Revadekar and Preethi (2012). At the aggregate level, Kapur (2018) show that excess/scanty rainfall has significant impact on agricultural activity. This paper extends the analysis by examining the effects of both insufficient and excessive rainfall during the monsoon season, utilizing district-level data to better reflect the spatial distribution of rainfall. Furthermore, we aim to identify the effects of rainfall in particular months of the monsoon season to account for the varying cropping cycles of different crops.

III. Data and Stylized Facts

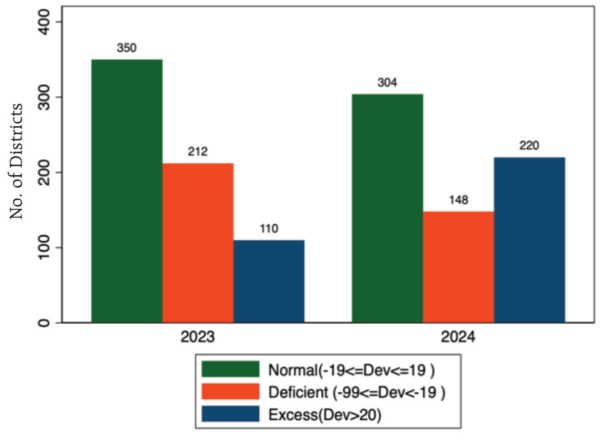
This paper uses data from India Meteorological Department (IMD) for spatial analysis of rainfall which are available at a daily and monthly frequency. The district-level agricultural production data are from Ministry of Agriculture, Government of India and collected from the Centre for Monitoring Indian Economy (CMIE) Commodities database to maintain consistency across years and districts.

The south-west monsoon in India is a seasonal wind pattern that brings the majority of the country's annual rainfall between June and September. It originates from the Indian Ocean and moves towards the Indian subcontinent, drawn by the heat of the landmass during summer. This monsoon is a critical part of India's climate and agriculture, providing essential rainfall for crops, especially during the *Kharif* season (June to October), which includes crops like rice, cotton, and pulses. After bouts of extreme heatwaves during the summer months, the south-west monsoon season in 2024 started with a deficit in June 2024 followed by an excess rainfall in July, August and September 2024. The spatial distribution of rainfall was uneven during the first two months but improved during the next two months. Districts with excess rainfall increased in 2024, while districts with deficient and normal rainfall decreased relative to 2023.

The spatial distribution of south-west monsoon rainfall in India for 2023 and 2024 shows that there was a decrease in number of districts experiencing normal rainfall in 2024 relative to 2023 (Chart 1a). However, the number of districts experiencing deficient rainfall became fewer while the number of districts with excess rainfall increased in 2024. The district dynamics show that 59 districts with normal

Chart 1: Rainfall Distribution 2023 vs. 2024

a. Rainfall Distribution by Categories



b. Rainfall Distribution by Districts and Categories

		2024 (No. of Districts)		
		Normal	**Deficient**	**Excess**
2023 (No. of Districts)	**Normal**	170	59	121
	Deficient	96	81	35
	Excess	38	8	64

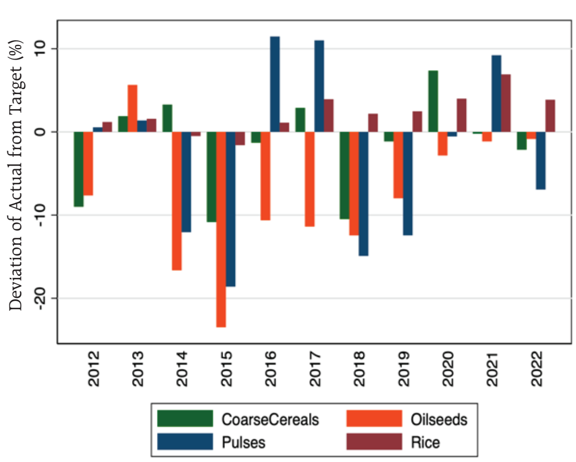
Notes: The categories of rainfall are based on the Indian Meteorological Department (IMD) definition. See https://mausam.imd.gov.in/imd_latest/monsoonfaq.pdf.
Source: IMD.

rainfall in 2023 experienced deficient rainfall in 2024, while 121 districts that received normal rainfall in 2023 saw excess rainfall in 2024 (Chart 1b). On the other hand, 96 districts that had deficient rainfall in 2023 recorded normal rainfall in 2024. Based on the underlying dynamics of spatial distribution, the net increase in districts with normal rainfall shifting from deficient conditions is 37, while net decrease in districts with normal rainfall shifting to excess rainfall is 83, comparing 2024 to 2023.

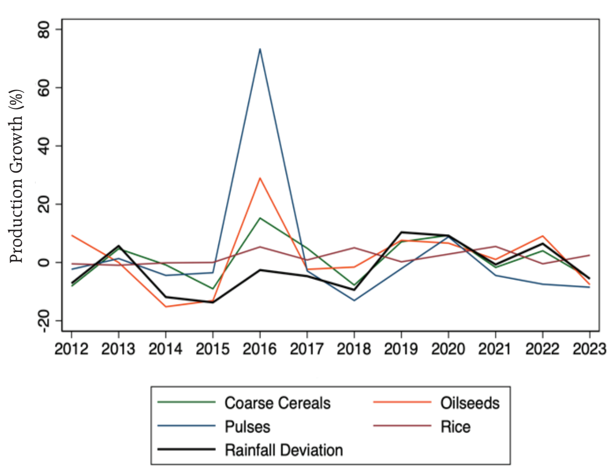
The difference in production pattern of different crop groups as compared to their targets shows that rice is the only crop that roughly meets the target production every year (Chart 2a). On the other hand, oilseeds and pulses consistently fall below the target

Chart 2: Production (Actual vs. Target) and Rainfall Deviation

a. Crop-wise Production Deviation



b. Crop-wise Production Growth



Source: Authors' estimates based on data from Directorate of Economics and Statistics, Department of Agriculture and Farmers Welfare and IMD.

production. The annual growth of the production of these four crop groups during the *Kharif* season indicates that there is a general trend of higher production during years when the south-west monsoon is better across all crops (Chart 2b). While rice production seems to follow a consistent pattern, other crops have a high dependence on monsoon rainfall, especially oilseeds and pulses. This is a known fact based on Indian agricultural pattern, while the consistency of rice production can be attributed to the high percentage of land under irrigation for rice production.

The above observations indicate that the spatial distribution of rainfall fluctuates from year to year. While it is clear that rainfall is important for *Kharif* crops, its effects on production differ among various crops depending on the magnitude and pattern of rainfall. This study seeks to examine the spatial distribution of rainfall and shed light on how it affects the production of different crops.

IV. Empirical Strategy

We match annual production data for each crop with rainfall at the district-level during the monsoon season. Additionally, we identify the month-year combinations during which the rainfall was deficient or excess. To gauge the impact spatial pattern of rainfall on crop production, we first use the following specification:

$$\ln(production)_{cdst} = \alpha_d + \theta_{st} + \beta_1 * \ln(Rainfall)_{dst} + \beta_2 * \ln(Rainfall)_{dst} * Deficient_{dst} + \beta_3 * \ln(Rainfall)_{dst} * Excess_{dst} + \beta_4 * \ln(Area\ Sown)_{dst} + \epsilon_{cdst} \quad \ldots (1)$$

Where $\ln(production)_{cdst}$ refers to the production (log) of crop *c* in district *d*, state *s* in year *t*. $\ln(Rainfall)_{dst}$ and $\ln(Area\ Sown)_{dst}$ refer to the actual rainfall and area sown in district *d*, state *s* and year *t*. $Deficient_{dst}$ and $Excess_{dst}$ takes the value 1 if there is deficient or excess rainfall in district *d* in year *t* otherwise zero, respectively. The variable of interest is β_1 which tells us the marginal impact of rainfall on crop production. Coefficients β_2 and β_3 provide the marginal impact of rainfall if a district experiences deficient or excess rainfall in the particular year. So, if all districts experienced normal rainfall in a particular year, the marginal effect of rainfall will be β_1. But if there are districts that experience deficient (or excess) rainfall during that year, the impact of rainfall is $\beta_1 + \beta_2$ (or $\beta_1 + \beta_3$).

We include district fixed effects (α_d) that control for any time invariant characteristics (*e.g.*, soil characteristics, long-term agroclimatic conditions), and any unobserved district level conditions that may influence production of a particular crop. The specification includes state specific year fixed effects (θ_{st}) that control for any macroeconomic events like policy changes (*e.g.*, minimum support prices, fertilizer subsidies, trade polices) or climatic changes (*e.g.*, *El Nino*, *La Nina*) that may occur in a particular year in a particular state which affect all districts in a state at the same time. The state specific year fixed effects also control for any state-level variables (*e.g.*, State GDP, credit, irrigation infrastructure at the state-level, *etc.*) that may influence the production process.

Since the cropping cycle differs across crops, we attempt to tease out the impact of deficient or excess rainfall in a particular month for each of the crops. To do this, we augment the first specification by including month wise interaction terms:

$$\ln(production)_{cdst} = \alpha_d + \theta_{st} + \beta_1 * \ln(Rainfall)_{dst} + \sum_{m = Jun, Jul, Aug, Sep} \beta_{2,m} * \ln(Rainfall)_{dst} * Deficient_{dstm} + \sum_{m = Jun, Jul, Aug, Sep} \beta_{3,m} * \ln(Rainfall)_{dst} * Excess_{dstm} + \beta_4 * \ln(Area\ Sown)_{dst} + \epsilon_{cdst} \quad \ldots (2)$$

Here, $Deficient_{dstm}$ (*if m = jun*) takes the value 1 if district '*d*' in year '*t*' experienced deficient rainfall in the month of June. Similarly for the other months and for the excess rainfall. Rest of the variables carry the same interpretation as in equation 1. In this specification, we try to delve deeper to see whether excess of deficient rainfall in a particular month during the monsoon seasons matters for crop production. Specifically, what is the aggregate marginal effect of rainfall on crop production if districts experience deficient or excess rainfall in the June, July, August or September. This is important because the water and soil moisture requirement are different across crops. For example, excess rainfall during the harvesting season generally leads to crop damages and is harmful for most crops. In fact, for pulses, excess rainfall during the flowering season and deficient rainfall during sowing season are harmful for the crops. Since this analysis requires both production and rainfall data at the district level, the time period is confined to 2012-2022 based on consistent data availability across districts. One advantage of keeping a recent period of data compared to historical data is the possibility of factoring out any long-term changes that may influence crop production at the district level. In all our specifications, we cluster the standard errors at the district level to account for any serial correlation within districts.

Since actual production of a crop in a district may depend on previous year's production, a dynamic panel specification is used as a robustnbess check that includes a lagged value of production. The results from this specification are presented in the Appendix Tables A.1-A.3.

V. Results

We estimate Equation 1 for total cereals production and two major crops: paddy and maize. The results reveal that rainfall plays a crucial role in influencing agricultural output, though its effects differ across crops (Table 1). A one per cent higher rainfall increases cereals production by 0.04 per cent, a 0.03 per cent rise in paddy production, and a 0.16 per cent increase in maize production. These results indicate that maize is more responsive to changes in rainfall than paddy, likely due to the crop's dependency on natural water sources in rainfed areas.

Table 1: Impact of Rainfall on Crop Production (Cereals)

	(1)	(2)	(3)
	Cereals	**Paddy**	**Maize**
ln Rainfall(Actual)	0.038* (0.019)	0.031* (0.017)	0.159** (0.071)
ln Rainfall*Deficient	-0.007*** (0.002)	-0.005** (0.002)	0.0002 (0.006)
ln Rainfall*Excess	-0.003 (0.002)	0.002 (0.002)	-0.011* (0.006)
ln AreaSown	1.049*** (0.040)	1.066*** (0.040)	1.065*** (0.026)
Constant	14.205*** (0.245)	14.245*** (0.229)	13.511*** (0.499)
District FE	Yes	Yes	Yes
State*Year FE	Yes	Yes	Yes
N	4165	3807	3278
R^2	0.95	0.96	0.97

Notes: Standard errors are clustered at the district * year level.
* p<0.10, ** p<0.05, *** p<0.01
Source: Authors' estimates.

The results also highlight the asymmetric effects of rainfall deviations. Deficient rainfall has marginally negative impact on total cereals and paddy production. Paddy's limited sensitivity to rainfall shortages can be attributed to the widespread use of irrigation systems in paddy cultivation, which buffers the crop against deficient rainfall. However, maize production remains unaffected by deficient rainfall, reflecting its adaptability and potential reliance on soil moisture or farming practices suited to low-rainfall conditions.

Excessive rainfall, on the other hand, emerges as a significant constraint, particularly for maize. Excess rainfall reduces maize production by 0.011 per cent from the baseline, indicating waterlogging or prolonged periods of standing water adversely affect this crop. This is consistent with maize's physiological characteristics, as it is highly sensitive to poor drainage and water accumulation.

Table 2 reports the regression results from equation 1 for pulses. Column 1 reports the results for overall pulses production while columns 2, 3 and 4 report the results for three major pulses grown during the *Kharif* season, namely, Arhar, Moong, and Urad. Results show that rainfall has a large positive impact on all pulses, except Moong for which rainfall is not statistically significant. A 1 per cent increase in rainfall increases overall pulses production by 0.33 per cent. Deficient rainfall seem to affect overall pulses and Arhar production and has a negative but statistically insignificant effect on Moong. Defcient rainfall seem to have positive effect on Urad production. Interestingly, excess rainfall seems to be quite harmful for all kinds of pulses. A pre-requisite for the success of Arhar and Moong is proper drainage. Ridge planting is effective in areas where sub-surface drainage is poor. This provides enough aeration for the roots during the period of excess rainfall. Overall, production of pulses seem to be quite sensitive to both deficient and excess rainfall. Thus, it requires the right amount of rainfall which is neither excess nor deficit.

We also estimate equation 1 for oilseeds, focusing on three major *Kharif* oilseeds, namely soyabean, groundnut and sunflower (Table 3). Rainfall seems to be important for overall oilseeds production with a one per cent increase in rainfall boosting production by 0.3 per cent. However, the individual responses on each of the crops are relatively weak. Deficient rainfall negatively affects oilseeds (except Sunflower) but none of the effects are statisticaly significant. Excess rainfall significantly reduces overall oilseeds production, particularly soyabean.

Soybean is a rainfed crop cultivated during the *Kharif* season and is sown only after the monsoon arrives. Farmers are advised to plant their crops only after receiving 100 mm of rainfall to ensure proper germination and steady growth. However, excess rain during the maturity stage can degrade soybean quality. While warm and humid conditions promote healthy growth, cool and wet weather hampers germination

Table 2: Impact of Rainfall on Crop Production (Pulses)

	(1)	(2)	(3)	(4)
	Pulses	**Arhar**	**Moong**	**Urad**
ln Rainfall(Actual)	0.333*** (0.107)	0.345*** (0.133)	0.203 (0.206)	0.466*** (0.130)
ln Rainfall*Deficient	-0.017** (0.008)	-0.018* (0.010)	-0.025 (0.019)	0.024*** (0.009)
ln Rainfall*Excess	-0.033*** (0.010)	-0.017* (0.010)	-0.054*** (0.020)	-0.038*** (0.009)
ln AreaSown	1.023*** (0.023)	1.034*** (0.039)	1.048*** (0.071)	1.016*** (0.030)
Constant	11.246*** (0.700)	11.253*** (0.894)	11.623*** (1.313)	9.982*** (0.875)
District FE	Yes	Yes	Yes	Yes
State*Year FE	Yes	Yes	Yes	Yes
N	3307	2519	1827	2603
R^2	0.95	0.96	0.97	0.96

Notes: Standard errors are clustered at the district * year level.
* p<0.10, ** p<0.05, *** p<0.01
Source: Authors'estimates.

Table 3: Impact of Rainfall on Crop Production (Oilseeds)

	(1)	(2)	(3)	(4)
	Oilseeds	**Soyabean**	**Groundnut**	**Sunflower**
ln Rainfall(Actual)	0.303** (0.143)	0.089 (0.084)	0.197 (0.184)	0.382 (0.316)
ln Rainfall*Deficient	-0.005 (0.010)	-0.013 (0.009)	-0.023 (0.025)	0.005 (0.020)
ln Rainfall*Excess	-0.036*** (0.010)	-0.036*** (0.009)	-0.001 (0.014)	0.0001 (0.016)
ln AreaSown	0.911*** (0.051)	0.910*** (0.042)	1.075*** (0.093)	1.028*** (0.046)
Constant	12.350*** (0.963)	13.710*** (0.585)	12.642*** (1.281)	11.171*** (1.888)
District FE	Yes	Yes	Yes	Yes
State*Year FE	Yes	Yes	Yes	Yes
N	2237	1160	1937	315
R^2	0.92	0.92	0.95	0.96

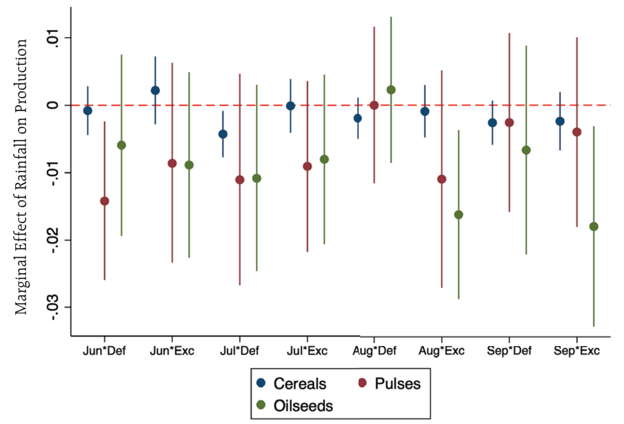
Notes: Standard errors are clustered at the district * year level.
* p<0.10, ** p<0.05, *** p<0.01
Source: Authors' estimates.

and increases the risk of seed rot. Although we do not find any significant effect of deficient or excess rainfall on groundnut, its production is sensitive to extreme conditions such as frost, severe drought, or standing water. Adequate rainfall is crucial during the flowering, pegging, and pod formation stages to achieve maximum yield and high-quality groundnuts.

Tables A.1-A.3 present the results from a dynamic panel specification. The impact of rainfall on production seems to be consistent with our baseline specification. The impact of deficient or excess rainfall, although being consistent in the direction of the effect, there are minor deviations in terms of statistical significance. For example, while excess rainfall has a statistically significant negative impact on pulses production in our baseline results, the dynamic panel estimation results are not statistically significant. On the other hand, deficient rainfall shows no significant impact on oilseeds production in our baseline specfication, but shows a negative and statistically significant effect in the dynamic panel specification. Considering these minor deviations, overall the results are found to be consistent across the two types of specifications.

The results in Table 1, 2 and 3 show how overall rainfall affect production of different crops while highlighting their vulnerability to deficient or excess rainfall. These estimates show the average of impact of deficient or excess rainfall during the entire monsoon season. However, the crop cycles are different for each of the crops based on the water requirement, soil moisture and the duration of the production cycle. For example, paddy fields must remain filled with sufficient water depths for at least 10 weeks during the growing season of the crop life cycle. On the other hand, maize must be sown at the optimum time when there is less chance of waterlogging. Similarly, pulses and oilseeds are grown during the *Kharif* season, although being dependent on rainfall, the timing and intensity of the rainfall matter.

Chart 3: Marginal Effect of Spatial Rainfall on Production



Note: The chart plots the monthly coefficient estimates along with the confidence intervals, based on latter equation specification. 'Def' and 'Exc' refer to the dummies for Deficient and Excess rainfall at the district level, respectively.
Source: Authors' estimates.

To account for the temporal aspect of rainfall while preserving its spatial variation, Equation 2 introduces monthly dummy variables for deficient or excess rainfall during the southwest monsoon season. The monthly coefficients show the marginal effect of deficient or excess rainfall in a particular month (Chart 3). The dots represent the point estimates while the vertical lines represent the 95 per cent confidence interval. The estimates show that the spatial and temporal distribution of rainfall significantly affects crop production. For cereals production, deficient rainfall in July adversely impacts production. Production of pulses is vulnerable to deficient rainfall during the sowing season, while excess rainfall in August and September is harmful for oilseeds production. Thus, depending on the sowing, germination and harvesting time of the crops, deficient or excess rainfall has a differential impact on the production.

VI. Conclusion

This article examines how rainfall affects *Kharif* crop production, with an emphasis on the spatial distribution of southwest monsoon. Our analysis highlights the critical role of rainfall in determining the production outcomes of various crops, emphasising the differential effects of timing, intensity, and distribution. The findings indicate that, on average, rainfall is crucial for crop production. While cereals, pulses, and oilseeds benefit from timely and adequate rainfall, deviations in the form of deficiency or excess during key growth stages can lead to significant losses. Given that crop cycles vary across crops, inadequate or excessive rainfall during the sowing and harvesting periods negatively affects overall production.

Our findings suggest that in areas prone to heavy rainfall, early planting is recommended so that maize plants reach a more robust stage of growth, making them better equipped to withstand such adverse conditions. Interestingly, given paddy's high water requirement, excessive rainfall may not significantly impact its production. Paddy's ability to tolerate standing water could be the reason behind its resilience to excessive rainfall.

Overall, the results underscore the need for region-specific and crop-specific water management strategies. While rainfall generally boosts production, excess rainfall poses significant challenges, particularly for maize, pulses and oilseeds. Policymakers and agricultural extension services could use these insights to promote crop diversification, improve drainage infrastructure, and encourage planting strategies that mitigate the risks of waterlogging, thereby enhancing resilience to rainfall variability. Policymakers and agricultural practitioners must focus on improving irrigation systems and adopting resilient crop varieties to mitigate the adverse effects of rainfall variability. By addressing these challenges, farmers can achieve more stable and sustainable crop yields despite the uncertainties posed by changing monsoon patterns.

As climate change causes extreme weather events, crop production faces growing risks. In a diverse country like India, the impact of climate change will differ across regions. Thus, further research is necessary to explore how the spatial distribution of these extreme events affects agricultural production and cropping cycles. This study is an attempt towards this end.

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Appendix

Table A.1: Impact of Rainfall on Crop Production (Cereals): Dynamic Panel Estimates

	(1)	(2)	(3)
	Cereals	**Paddy**	**Maize**
ln Production(lagged)	0.929***	0.954***	0.888***
	(0.009)	(0.009)	(0.024)
ln Rainfall(Actual)	0.058***	0.034*	0.181***
	(0.018)	(0.020)	(0.052)
ln Rainfall*Deficient	-0.008***	-0.004*	-0.007
	(0.003)	(0.002)	(0.009)
ln Rainfall*Excess	-0.000	0.003	-0.007
	(0.003)	(0.004)	(0.008)
ln AreaSown	0.206***	0.133***	0.287***
	(0.020)	(0.016)	(0.035)
District FE	Yes	Yes	Yes
State*Year FE	Yes	Yes	Yes
N	3575.00	3248.00	2737.00

Notes: Standard errors are clustered at the district * year level.
* p<0.10, ** p<0.05, *** p<0.01
Source: Authors' estimates.

Table A.2: Impact of Rainfall on Crop Production (Pulses): Dynamic Panel Estimates

	(1)	(2)	(3)	(4)
	Pulses	**Arhar**	**Moong**	**Urad**
ln Production(lagged)	0.797***	1.021***	0.894***	0.809***
	(0.041)	(0.069)	(0.084)	(0.078)
ln Rainfall(Actual)	0.245***	-0.162	0.004	0.292*
	(0.094)	(0.152)	(0.179)	(0.168)
ln Rainfall*Deficient	-0.026**	-0.050***	-0.046**	0.027**
	(0.011)	(0.016)	(0.020)	(0.011)
ln Rainfall*Excess	-0.010	0.005	-0.005	-0.026*
	(0.011)	(0.017)	(0.022)	(0.015)
ln AreaSown	0.480***	0.205***	0.314***	0.323***
	(0.043)	(0.069)	(0.084)	(0.064)
District FE	Yes	Yes	Yes	Yes
State*Year FE	Yes	Yes	Yes	Yes
N	2741.00	2078.00	1447.00	2149.00

Notes: Standard errors are clustered at the district * year level.
* p<0.10, ** p<0.05, *** p<0.01
Source: Authors' estimates.

Table A.3: Impact of Rainfall on Crop Production (Oilseeds): Dynamic Panel Estimates

	(1)	(2)	(3)	(4)
	Oilseeds	**Soyabean**	**Groundnut**	**Sunflower**
ln Production(lagged)	0.940***	0.768***	1.157***	0.721***
	(0.042)	(0.054)	(0.094)	(0.050)
ln Rainfall(Actual)	0.118	0.362***	-0.292	0.534***
	(0.083)	(0.114)	(0.188)	(0.104)
ln Rainfall*Deficient	-0.020*	-0.002	-0.085**	-0.071***
	(0.012)	(0.012)	(0.041)	(0.024)
ln Rainfall*Excess	-0.014	-0.050***	0.057*	0.005
	(0.010)	(0.012)	(0.031)	(0.022)
ln AreaSown	0.183***	0.340***	-0.073	0.614***
	(0.051)	(0.059)	(0.099)	(0.068)
District FE	Yes	Yes	Yes	Yes
State*Year FE	Yes	Yes	Yes	Yes
N	2426.00	966.00	1564.00	238.00

Notes: Standard errors are clustered at the district * year level.
* $p<0.10$, ** $p<0.05$, *** $p<0.01$
Source: Authors' estimates.