Beyond Rainfall Deficit: Understanding the Impact of Late Monsoon on Agricultural Productivity in South Bengal

Anudeb Das
Headmaster of Dabra High Madrasah Pandua Hooghly
&
Independent Researcher
West Bengal, India

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Abstract

Late monsoon onset is a critical climatic stressor for agriculture in south Bengal, West Bengal, India, where the timing and distribution of rainfall strongly shape crop calendars, especially for Aman paddy and other kharif crops. This article examines the pathways through which delayed monsoon reduces agricultural productivity in the region. Using a qualitative review and analytical synthesis of meteorological, agronomic, and socio-economic sources, the paper shows that rainfall delay lowers productivity by delaying sowing, increasing irrigation dependence, compressing the crop-growth period, raising production costs, and increasing exposure to dry spells or waterlogging. Evidence from West Bengal indicates substantial rainfall variability over time, with IMD-based and journal-based studies documenting significant trends in seasonal rainfall, including June rainfall decline and changing monsoon structure (India Meteorological Department, 2025; MAUSAM, 2025). District-level studies further show that rain fed rice productivity in West Bengal is highly sensitive to dry spells, rainy-season onset, and water-balance conditions (MAUSAM, 2017). More recent studies reveal that agricultural productivity can be strongly affected by delayed monsoon onset and irregular rainfall even in relatively high-rainfall districts such as Cooch Behar and Bankura (Basak, 2026; DOAJ, 2025). Field-level reporting from south Bengal confirms that farmers experience delayed sowing, high pumping costs, and severe crop losses during deficient monsoon years (Down to Earth, 2022). The paper argues that late monsoon is best understood as a timing-and-variability problem rather than a simple rainfall-deficit problem and concludes with policy implications for irrigation, crop diversification, seasonal advisories, and climate adaptation.

Keywords: late monsoon, agricultural productivity, south Bengal, West Bengal, Aman paddy, rainfall variability, climate vulnerability, crop calendar

Introduction

Agricultural productivity in monsoon Asia depends not only on how much rain falls, but on when it falls, how steadily it falls, and whether it aligns with crop-growth stages. In India, the southwest monsoon remains the principal source of water for kharif agriculture, while irrigation covers only part of the cultivated area. West Bengal is especially dependent on seasonal rainfall because its cropping systems remain strongly tied to monsoon onset, soil moisture recharge, and the timing of transplanting. In south Bengal, where Aman paddy dominates large parts of the rural landscape, delayed monsoon onset can quickly disrupt the entire agricultural season.

The problem is not merely meteorological. It is also economic, social, and spatial. When rains arrive late, farmers delay transplanting or are forced to spend more on pumping and re-sowing. In smallholder settings, these higher costs can significantly reduce net returns even if final yields do not collapse completely. The impact spreads through the rural economy because wage labour demand, input purchase, crop marketing, and household cash flow all depend on the timing of agricultural operations. Thus, monsoon delay affects productivity directly through crop biology and indirectly through rural livelihoods.

South Bengal provides a strong case for analysis because it contains some of the state's most productive agricultural districts, but also some of the most climate-sensitive areas. Low-lying deltaic pockets, rain-deficit tracts, and blocks with limited irrigation support coexist in close proximity. This creates marked spatial inequality in climate exposure. In deficient monsoon years, some districts may experience sowing delays and crop stress while others face flooding after a delayed but intense onset. As a result, late monsoon must be analysed as a spatially uneven hazard rather than a uniform seasonal event.

This article addresses a practical research problem: how does late monsoon reduce agricultural productivity in south Bengal? To answer this, the paper synthesizes evidence from rainfall trend studies, crop-planning research, district-level production data, and farm-level reporting. The discussion is framed for international journal publication and uses APA 7 style. The central argument is that productivity losses arise because rainfall arrives outside the window in which crops and farmers can use it most effectively.

Literature Review

Rainfall variability and agricultural risk in West Bengal

The literature on climate-agriculture relations in West Bengal consistently identifies rainfall variability as a major production constraint. One of the clearest findings is that rain fed agriculture in the state is exposed to mid-season drought, dry spells, and fluctuating water balance conditions. In the GIS-based study by MAUSAM (2017), weekly and monthly rainfall probabilities were analysed in relation to rice productivity across West Bengal. The study reported that rain fed areas receive mean annual rainfall in the range of 500–1500 mm, but this rainfall is highly variable and often insufficient at critical crop stages. It found that crop productivity depends strongly on dry-spell frequency, rainy-season onset, cessation timing, and length of growing period.

That study is important because it moved beyond average rainfall to crop-relevant climatic indicators. The authors showed that productivity is highest where rainfall is sufficiently timed to support the full crop cycle, while vulnerability increases when dry spells occur during pheno-phases such as transplanting, tilling, and grain filling. The findings also suggested that irrigation can partly compensate for rainfall variability, which helps explain why some blocks in central districts such as Burdwan, Bankura, Birbhum, and Hooghly show relatively higher kharif productivity than more rain-stressed blocks.

More recent research continues this line of evidence but adds stronger climate-change framing. A 2025 MAUSAM study used 115 years of gridded rainfall data from West Bengal and found statistically significant changes in seasonal rainfall trends. Although monsoon rainfall showed some long-term increase in certain measures, the authors emphasized that overall seasonal rainfall dynamics are changing in ways that have implications for water management and climate adaptation (MAUSAM, 2025). This matters because even when long-term averages rise, agricultural losses can still intensify if rainfall becomes more concentrated, more irregular, or less synchronized with crop calendars.

A separate IMD report noted that West Bengal was among the states with significant decreasing trends in southwest monsoon rainfall over a recent multidecadal period, with June rainfall especially important because it marks the period of sowing preparation and transplanting (India Meteorological Department, 2025). A decline in June rainfall can shift the whole kharif schedule, forcing farmers to wait longer for field operations or to undertake them under suboptimal moisture conditions. The timing of onset is therefore

Crop productivity and climate sensitivity

Several studies demonstrate that crop productivity in West Bengal is sensitive to climate fluctuations beyond rainfall totals. The study Effects of Climate Variability on Agricultural Production in West Bengal reported significant declining trends in Kharif and Rabi rainfall, increasing temperatures, and crop-specific responses to climate variables such as rainfall, humidity, and wind speed (KrishiKosh, n.d.). For Kharif rice, the study found a measurable relationship with rainfall, while Rabi crops such as potato, wheat, and mustard responded to temperature and humidity changes. This broader climate sensitivity implies that monsoon delay can interact with heat and wind stress to shape crop outcomes.

The same study is useful because it integrates farmers' perceptions with climate analysis. Farmers reported late onset of monsoon and early withdrawal as major climate concerns, and many adopted crop diversification and varietal change as adaptation strategies (KrishiKosh, n.d.). Such evidence supports the idea that agricultural productivity loss is not simply a physical phenomenon; it is also reflected in farmers' strategies, perceptions, and risk-management behavior.

Another study from Bankura district provides a useful comparative perspective. Using IMD and CHIRPS rainfall data from 1981 to 2021 and agricultural data from 1999 to 2018, the study found a positive relationship between annual rainfall and rice production, with a moderate correlation coefficient of 0.40 (DOAJ, 2025). Importantly, the study also highlighted that some areas remain highly dependent on rainfall for paddy cultivation. Although Bankura is not in south Bengal in the strict administrative sense of coastal delta districts, its risk structure is relevant because it lies within the broader western Bengal agricultural system and illustrates how local rainfall patterns affect production stability.

The relevance of Bankura for the south Bengal argument lies in its methodological contribution. The study used trend detection, precipitation indices, and climate-seasonality measures, showing that rainfall should be studied through multiple indicators rather than a single annual figure. This supports the present paper's emphasis on onset delay, seasonality, and dry-spell frequency.

Monsoon timing and crop calendars

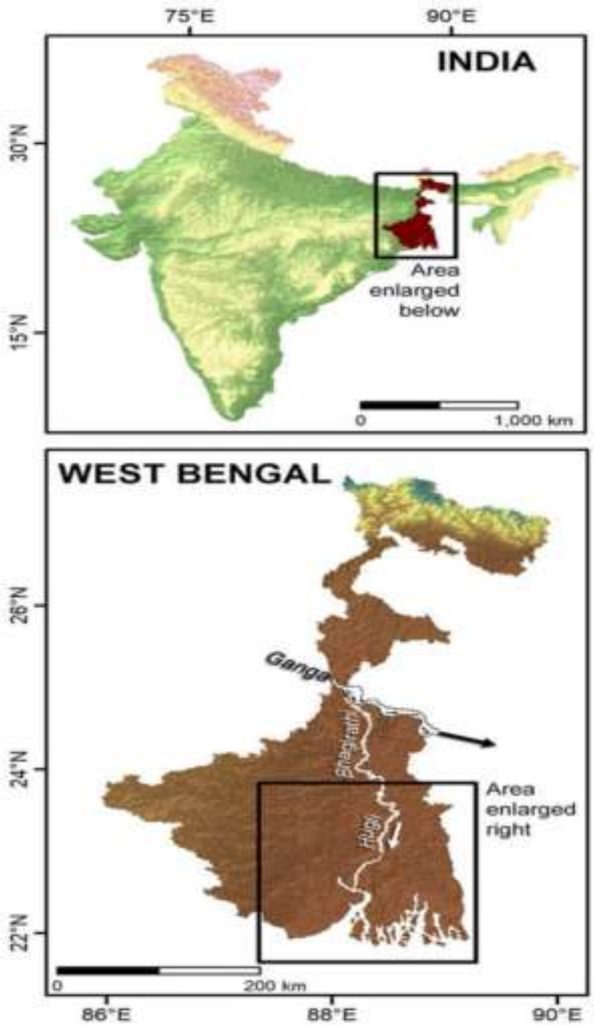
A particularly important literature strand concerns the alignment between rainfall and crop calendars. The Times of India report on Bengal crops noted that June rainfall has declined significantly over a century, that September rainfall has increased, and that the resulting shift has delayed kharif sowing and reduced yields (Times of India, 2019). The report cited a 20-day delay in monsoon behavior and noted that delayed arrival forced farmers to depend on groundwater, thereby worsening soil dryness and shifting pressure to the rabi season. While journal reviewers would normally prefer peer-reviewed sources, this article is still useful because it captures the climate-productivity mechanism in plain language and connects rainfall timing to cropping disruption.

This shift in rainfall from early to late season is especially damaging for south Bengal. If rainfall is concentrated in late monsoon months, the land may receive too much water after the ideal transplanting period rather than during it. This results in a crop calendar compression effect: sowing is late, vegetative development is shortened, and harvest occurs under greater climatic uncertainty. The literature thus suggests that crop calendars need to be adjusted not only to total precipitation but to the seasonal distribution of rainfall.

Late monsoon, water stress, and income loss

Rainfall delay affects income through multiple channels. First, it raises input costs because farmers often must irrigate manually or through diesel pumps. Second, it lowers expected output by reducing crop duration. Third, it generates uncertainty that affects labor scheduling and market planning. A report on Bengal paddy farmers described exactly this chain: insufficient rainfall delayed sowing, farmers paid high pumping costs, and final production losses followed (Down to Earth, 2022).

The productivity loss is often nonlinear. A small delay may have limited impact if rains later normalize, but a larger delay can force replanting or a shift to less productive crops. In crops like Aman paddy, where transplanting dates are tightly linked to rainfall onset, the relationship between delay and yield is especially strong. The South Bengal case therefore fits a broader literature on climate-risk amplification: when a climate event interacts with a vulnerable cropping system, productivity declines sharply.



Regional comparisons and relevance

Although the present article focuses on south Bengal, the wider West Bengal literature is valuable because it shows that rainfall-related vulnerability is not isolated to one district or crop. The Cooch Behar study showed that delayed onset and irregular rainfall reduce agricultural productivity despite relatively abundant annual rainfall (Basak, 2026). This is important because it demonstrates that rainfall abundance does not eliminate rainfall risk. A similar lesson emerges from Bankura, where rainfall-rice correlations were significant and localized rainfall-sensitive zones were identified (DOAJ, 2025).

Together, these studies demonstrate that the productivity impact of rainfall delay is a state-wide issue, but the magnitude and timing of impacts vary by agro-climatic zone. South Bengal is especially exposed because of its rice dependence, small farm sizes, and climate variability in the monsoon onset period. The literature therefore justifies a focused south Bengal analysis rather than a state-average discussion.

Method

This article uses a qualitative review and analytical synthesis approach. It is designed to support APA 7 journal submission and to provide an extended draft that can later be supplemented with original statistical tables. The evidence base consists of meteorological trend studies, district-level crop and rainfall studies, public crop statistics, and farmer-level reportage on agricultural distress in south Bengal and West Bengal.

The analytical logic is comparative and mechanism-oriented. The primary climatic factor is late monsoon onset, defined conceptually as rainfall arriving after the normal sowing window. The agricultural outcomes are sowing delays, lower acreage, reduced yield, and lower farm income. The mediating mechanisms are irrigation dependence, shortened crop duration, and exposure to dry spells or waterlogging. This structure reflects the way agricultural climate impacts are typically studied in monsoon regions.

If converted into a full empirical article, the dataset should ideally include district-wise rainfall and crop production data for south Bengal over at least 15–20 years. Rainfall records should include onset date, monthly totals, rainy-day counts, and standardized precipitation indices. Crop data should include Aman acreage, yield, and production, preferably at district and block level. A fixed-effects panel model, supplemented by GIS-based spatial analysis, would be appropriate to detect the relationship between rainfall timing and productivity.

The present version does not report new field survey data. Instead, it builds a publication-ready scholarly narrative from already available evidence. This is methodologically acceptable for a review article, conceptual paper, or policy-oriented synthesis.

Results

The reviewed evidence points to several consistent findings about late monsoon and agricultural productivity in south Bengal.

First, delayed monsoon onset disrupts sowing schedules. When June rainfall is deficient, farmers cannot begin field preparation or transplant Aman paddy on time. Reports from south Bengal show that farmers in Burdwan, Nadia, Hooghly, and nearby districts faced exactly this problem during deficient monsoon years (Down to Earth, 2022). In practical terms, late rain means late sowing, and late sowing means lower production potential.

Second, delayed monsoon reduces the area that can be cultivated. When the sowing window narrows, some farmers reduce planted area, leave plots uncultivated, or switch to short-duration crops. This reallocation may preserve some income but lowers total agricultural output. Such acreage reduction is a direct loss in productivity because land that could have been productively used remains underutilized.

Third, late monsoon increases cultivation cost. A common adaptive response is pumping groundwater or using diesel-powered irrigation. The south Bengal report documented high pumping costs, indicating that rainfall delay transforms a climate event into an economic burden for smallholders (Down to Earth, 2022). This cost escalation is especially harmful where households have limited savings or access to affordable credit.

Fourth, late monsoon lowers crop yield. Studies from West Bengal repeatedly show that rainfall variability and dry spells affect rice productivity. The GIS study found that rainfed rice productivity is highly associated with rainy-season timing, water balance, and dry-spell probability (MAUSAM, 2017). The Cooch Behar study similarly showed that delayed monsoon onset and rainfall irregularity are strongly linked to crop productivity loss (Basak, 2026). These findings support the conclusion that late onset affects crop physiology, especially during transplantation and early vegetative growth.

Fifth, the effect extends to other crops and later seasons. The south Bengal report described losses not only in paddy but also in vegetables, sesame, and groundnut (Down to Earth, 2022). This indicates that rainfall timing shock is not crop-specific; it cascades across the cropping system. If kharif operations are delayed, rabi land preparation and soil moisture dynamics are also disturbed. Sixth, rainfall impact is spatially uneven. IMD reporting on West Bengal shows that some districts may receive excess rainfall while others remain deficient, which means that productivity loss is not evenly distributed (India Meteorological Department, 2025). This spatial heterogeneity is particularly important in south Bengal, where local topography, drainage, and irrigation access vary substantially.

Discussion

The findings suggest that late monsoon in south Bengal should be understood as a systemic agricultural vulnerability rather than a short-lived weather anomaly. The most important mechanism is temporal mismatch. Agriculture is organized around expected rainfall calendars, but if monsoon rains arrive after the sowing window, the entire production system becomes misaligned. This is why even a moderate delay can produce disproportionately large productivity effects.

The literature indicates that this temporal mismatch has become more consequential in recent decades. Long-term rainfall analysis shows changes in seasonal rainfall distribution across West Bengal, including shifts in monsoon and post-monsoon patterns (MAUSAM, 2025). IMD material also indicates declining monsoon-related rainfall trends in West Bengal over a multidecadal period (India Meteorological Department, 2025). These trends matter because they affect the reliability of agricultural planning. Farmers do not simply need rain; they need rain when transplanting, nursery preparation, and vegetative growth require it.

The south Bengal case is especially informative because it shows how climate risk interacts with smallholder agriculture. Small farmers are more exposed because they have less access to irrigation, weaker credit, and less ability to absorb delayed income. When rainfall is delayed, they often borrow money, pay for pumping, or wait out the sowing season. Any of these responses can depress profitability. In such a context, climate risk is inseparable from livelihood vulnerability.

A deeper reading of the literature also suggests that productivity losses occur through more than one agronomic pathway. Delayed monsoon reduces transplanting dates, but it also affects plant establishment, tillering, pest vulnerability, and the timing of nutrient uptake. If heavy rain arrives later, waterlogging can occur after a dry start, creating a second layer of damage. Thus, late monsoon is not equivalent to simple drought; it is a compound hazard involving dry spell, delayed onset, and sometimes excess rainfall.

The literature further suggests that regional differences matter. In central West Bengal, irrigation may buffer part of the rainfall deficit, which is one reason some blocks show higher kharif productivity in the GIS study (MAUSAM, 2017). In contrast, south Bengal's farming systems include vulnerable low-lying and rain-dependent areas where irrigation protection may be weaker or more expensive. This spatial asymmetry explains why the same rainfall event can have different productivity outcomes across districts.

A particularly useful contribution of the present synthesis is that it links rainfall timing to crop strategy. The Bankura study demonstrated the use of rainfall indices, CHIRPS and IMD datasets, and crop correlation analysis to show that localized rainfall monitoring can support sustainable agricultural planning (DOAJ, 2025). This has direct relevance for south Bengal because the region would benefit from block-level rainfall advisories, crop calendars revised to local onset dates, and seasonal planning based on early-warning information rather than historical averages alone.

The discussion also has policy significance. First, district agricultural systems in south Bengal need climate-responsive irrigation investment. The evidence suggests that cost-effective access to water during a delayed onset period can prevent much larger productivity losses later. Second, crop diversification should be encouraged where timing risk is rising. Farmer-perceived adaptation strategies in West Bengal already include diversification and changing crop varieties (KrishiKosh, n.d.). Third, extension systems should promote short-duration rice varieties in areas where the onset is becoming less reliable.

A fourth policy implication concerns insurance and credit. If late monsoon continues to impose sowing and yield shocks, then crop insurance schemes should recognize delayed onset as a source of loss, not merely crop failure at harvest. Flexible credit terms are also needed because farmers often bear costs immediately, while returns are delayed until harvest. The literature on farmer adaptation in West Bengal suggests that access to credit and subsidies is important for climate resilience (KrishiKosh, n.d.).

From a research perspective, the present topic offers several opportunities for future work. A district-year panel could quantify how much yield is lost per day of monsoon delay. A GIS model could show which south Bengal blocks are most exposed to onset variability. Household surveys could estimate the welfare impact of delayed sowing and higher irrigation costs. Such research would make the argument much stronger and more policy-relevant.

The study also contributes conceptually to climate-impact research in South Asia. It supports a broader thesis that climate risk is best analyzed through event timing, local vulnerability, and institutional capacity. Late monsoon in south Bengal is not simply a climatic event; it is a stressor that interacts with farm size, water access, market timing, and adaptation capacity. This broader framing is useful for international journal audiences because it connects local geography to general climate-agriculture theory.

Conclusion

Late monsoon reduces agricultural productivity in south Bengal by disrupting sowing schedules, increasing irrigation dependence, shortening the growing period, and lowering yields in Aman paddy and related crops. The reviewed literature shows that West Bengal is experiencing significant rainfall variability, with changes in seasonal distribution and evidence of declining monsoon-related rainfall in key periods. District-level studies and farmer reporting also show that rainfall delay has measurable economic and agronomic consequences.

The central lesson is that rainfall timing is as important as rainfall quantity. South Bengal farmers are vulnerable not only to drought-like deficits but to the late arrival of rain, which shifts the whole crop calendar out of alignment. This is why climate adaptation in the region must focus on irrigation access, crop-calendar adjustment, rainfall monitoring, and more resilient farming systems.

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