Research Paper IMPACT FACTOR VALUE : 5.983 | E-ISSN NO : 2455-295X | VOLUME : 11 | ISSUE : 11 |NOVEMBER 2025

UNSEASONAL RAINFALL IN INDIA AND INDIAN AGRICULTURE – A STUDY

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ABSTRACT:

Unseasonal rainfall—precipitation outside the expected seasonal window—has become an increasingly frequent and damaging phenomenon in India. This paper explores its causes, characteristics, and multifaceted impacts on Indian agriculture. Using climatological, agronomic, and socioeconomic perspectives, the study examines patterns of unseasonal rainfall in recent years (2023–2025), how they affect crop phenology, yields, farm incomes, input use, and risk profiles, and the coping and adaptation strategies adopted by farmers. It also discusses policy implications, including extension services, insurance, and climate-resilient agricultural planning. The findings reveal that unseasonal rains significantly disrupt cropping cycles, increase post-harvest losses, raise pest and disease risks, and impose heavy income losses—especially for small and marginal farmers. The paper concludes with recommendations to strengthen early warning systems, diversify cropping patterns, improve institutional support, and build climate resilience into India's agricultural framework.

KEYWORDS:

UNSEASONAL RAINFALL, ERRATIC PRECIPITATION, CROPPING CYCLES, YIELD SHOCK, CLIMATE ADAPTATION, INDIA AGRICULTURE.

PAPER ACCEPTED DATE:	PAPER PUBLISHED DATE:
18th October 2025	6th November 2025
PAPER DOI NO:	**PAPER DOI LINK:**
10.5281/zenodo.17545205	https://zenodo.org/records/17545205

INTRODUCTION

Agriculture in India is highly dependent on seasonal rainfall patterns and monsoon dynamics. The traditional rhythm of sowing, growing, harvesting, and fallow periods is deeply tied to predictable rainfall windows. However, in recent years, **unseasonal rainfall**—rainfall occurring outside expected seasons (before or after the monsoon, or during off-season months)—has emerged as a serious challenge. These aberrant rains disrupt multiple phases of crop growth, damage standing crops, trigger floods and water logging, and aggravate pest and disease pressures.

Given that over 50% of India's net sown area is rainfed and that many small and marginal farmers lack irrigation or buffer capital, unseasonal rains exacerbate vulnerability and income volatility. This paper investigates the patterns, causes, and consequences of unseasonal rainfall in India, particularly during 2023–2025, and its effects on Indian agriculture. It further explores adaptation, mitigation, and policy responses to reduce agricultural losses and strengthen resilience.

LITERATURE REVIEW

Agriculture in India is inherently reliant on predictable seasonal rainfall and monsoon patterns, which dictate the traditional rhythm of sowing, growing, and harvesting. However, unseasonal rainfall—defined as precipitation outside the normative period for a given region or cropping season—has emerged as a major challenge. This includes various forms such as pre-monsoon rains, post-monsoon aberrations, untimely showers during crop sensitive phases, hailstorms, and short-duration extreme events.

The phenomenon is intrinsically linked to climate variability and extremes. Climate change exacerbates the frequency of erratic precipitation, intensifies short-duration rainfall events, and disrupts the intra-seasonal distribution of rain. India has witnessed an increase in extreme rainfall events, notably in the north-eastern and peninsular regions.

RESEARCH METHODOLOGY

The study adopts a multifaceted approach to analyze the causes, characteristics, and consequences of unseasonal rainfall on Indian agriculture.

Climatological Analysis: The research examines recent patterns of unseasonal rainfall, specifically covering the period of 2023–2025, to understand their characteristics.

It draws upon data and trends, including gridded rainfall data from the India Meteorological Department (IMD4) merged with district-level agricultural data (1901–2021), to analyze rainfall anomalies and their influence on yield fluctuations.

Agronomic Perspective: The methodology explores the impacts on crop phenology, examining how unseasonal precipitation events affect various crop growth phases, from planting and flowering to maturity and harvest. Case evidence, such as the heavy rains in Central and Southern India in May 2025 and the flooding in Punjab in August 2025, are used to illustrate immediate agricultural damage and losses.

Socioeconomic Evaluation: The paper assesses the effects on farm incomes, input use, and risk profiles, particularly for small and marginal farmers. It incorporates anecdotal reports of farmer distress and suicides following events like the March 2015 unseasonal rains.

Policy and Strategy Review: The study examines existing coping and adaptation strategies adopted by farmers and discusses policy implications, focusing on insurance, extension services, and climate-resilient planning.

CONCEPTUALIZING UNSEASONAL RAINFALL AND CLIMATE VARIABILITY

DEFINITION AND TYPES

- *Unseasonal rainfall* refers to precipitation events occurring outside the normative period for a given region or cropping season (e.g., rains during February–March, or late rains after harvest).
- There are various forms: pre-monsoon rains, post-monsoon aberrations, unseasonal showers during flowering or maturity periods, short-duration extreme events (cloudbursts), hailstorms, and untimely drizzles during harvest.

LINK WITH CLIMATE VARIABILITY AND EXTREMES

- Climate change intensifies short-duration rainfall extremes, increases frequency of erratic precipitation, and disrupts intra-seasonal distribution of rainfall.
- India has seen an upward trend in extreme rainfall events, especially in peninsular and north-eastern regions, even if overall seasonal rainfall trends are less clear.

  Regional studies show shifts and fluctuations in monsoon timing, delayed withdrawal, and increasing variability in the frequency and intensity of rainfall pulses

DRIVERS OF UNSEASONAL RAINFALL

- Disturbance systems: western disturbances, low-pressure systems, cyclonic remnants, and cloud clusters can trigger rainfall outside the monsoon window.
- Land–atmosphere feedbacks: soil moisture anomalies, evapotranspiration patterns, deforestation, irrigation changes affect local humidity and convective rainfall.
- Teleconnections: remote climatic patterns (e.g., El Niño–Southern Oscillation, Indian Ocean Dipole) influence monsoon breaks and extreme rainfall occurrence.
- Anthropogenic climate change: warming enhances the moisture-holding capacity of air, leading to more intense rainfall events when conditions permit.

RECENT PATTERNS AND CASE EVIDENCE (2023–2025)

1. UNSEASONAL RAINFALL IN 2025

- In May 2025, several parts of Central India recorded ~5 times the usual rainfall, while southern India saw ~2.5 times the typical May precipitation. This rain occurred well before the formal monsoon onset, disrupting planting plans.
- These unseasonal rains defied forecasts and caused damage to early-sown crops, soil erosion, and increased disease pressure.
- In late 2025, heavy rains hit Karnataka's Kalaburagi region, impacting cotton, pigeon pea, green gram, and other crops via waterlogging and flooding
- Torrential rains in Rajasthan led to losses of 30–40% in Kharif crop area, with soybean, moong, bajra and other staples affected.
- In Punjab in August 2025, floods caused by high monsoon rains and dam releases inundated over 2.5 lakh acres of farmland, damaging rice and cotton.

HISTORICAL ILLUSTRATIVE EVENTS

- In March 2015, unseasonal rains and hailstorms in North India destroyed Rabi crops over ~106 lakh hectares, causing huge losses and triggering distress among farmers.
- More broadly, climatological reviews show that the frequency of extreme point rainfall events has increased in many sub-regions of India, particularly peninsular, east, and northeast India

STATISTICAL AND GRIDDED DATA TRENDS

- A study using gridded rainfall from IMD (IMD4) merged with district-level agricultural data (1901–2021) shows rainfall anomalies and temperature interactions significantly influencing yield fluctuations.
- State-wise and subdivision rainfall trend data from government sources reflect both positive and negative monthly trends, illustrating heterogeneity across India
- In the Thanjavur delta region, observed rainfall trends over 1971–2014 show slight changes, though uncertain for unseasonal patterns.

- These recent examples and data underline that unseasonal rainfall is not isolated — it is becoming a more frequent disruption in India's agricultural calendar, demanding deeper inquiry into impacts and responses.

MECHANISMS OF IMPACT ON AGRICULTURE

Unseasonal rainfall affects agriculture through multiple mechanistic pathways, depending on timing, intensity, duration, crop stage, and local conditions.

DISRUPTION OF PLANTING AND SOWING SCHEDULES

- Pre-monsoon unseasonal rain may delay or hamper land preparation, seedbed readiness, fertilizer application, and weed control.
- Excess moisture early may cause water logging and soil crusting, reducing seed germination or damaging seedlings.
- It may force farmers to postpone sowing or re-sow crops at sub-optimal timings, reducing the effective growing window and crop vigor.

DAMAGE TO STANDING CROPS

- When rainfall occurs during flowering, grain-filling, or maturation, it can cause lodging, shattering, sterility, or unfilled grains.
- Water logging leads to root hypoxia (lack of oxygen), nutrient leaching, and fungal diseases (e.g. panicle blast, rots).
- Post-harvest unseasonal rains hamper harvesting operations, reduce quality, and increase losses due to spoilage, sprouting, or pest/disease infestation.

SOIL EROSION, NUTRIENT LOSSES, AND DEGRADATION

- Intense rain events produce surface runoff and soil erosion, stripping topsoil and organic matter.
- Nutrient leaching, particularly of nitrogen and potassium, reduces soil fertility.
- Structural damage to soil (compaction, crusting) retards infiltration in subsequent seasons.

PEST, DISEASE, AND WEED DYNAMICS

- Humid and moist environments created by unseasonal rains favor pathogen proliferation (fungi, bacterial blight, mildew) and insect outbreaks.
- Without predictable dry spells, fungicide and pesticide schedules may be disrupted.
- Weed germination may shift unpredictably, making weed management harder.

2. INPUT LOSSES AND COST ESCALATION

- Seeds may rot or get washed away, fertilizers may get leached or wasted, and labor for weeding, pest control, and drainage increases.
- Mechanized harvesting or drying operations become harder, pushing up reliance on manual labor and costs.

YIELD SHOCKS AND INCOME VOLATILITY

- The combined disruptions can lead to sharp yield declines.
- For small and marginal farmers with limited buffer resources, such shocks can push them into debt and distress.
- Market price fluctuations may compound losses if supply disruptions or quality defects occur.

EMPIRICAL IMPACTS: YIELD LOSSES, INCOME, AND FARM DISTRESS

QUANTIFYING YIELD DECLINE

- A report by FICCI on "Impact of Unseasonal Rains" notes that crop output drops significantly when unseasonal precipitation hits sensitive phases. The report points to widespread lower yields, reduced farm incomes, and credit stress for farmers.
- In a climate modeling and adaptation study, projections suggest that rice yield declines of 10–30% and maize declines of 2–12% may result due to precipitation pattern changes.
- The Indian Agricultural Research Institute estimates that a 10% reduction in rainfall could reduce rice yields by 7–8%.

INCOME AND FINANCIAL STRESS

- Lower yields directly translate into reduced farm income, especially for cash crops or high-cost inputs. FICCI's study mentions that failure to recover input costs or service loans leads to farmer stress.

There are anecdotal reports in episodes like March 2015 where massive crop loss led to farmer distress and some suicides.

CASE-LEVEL DAMAGE REPORTS

- In Rajasthan in 2025, torrential rains caused 30–40% crop damage in Kharif area across districts, severely affecting soybean, bajra, moong, etc. The Times of India
- In Kalaburagi, Karnataka, heavy rains in late 2025 impacted multiple crops over 2.9 lakh hectares; cotton, pigeon pea, green gram faced water logging, yield loss.
- Punjab floods in 2025 inundated large agricultural lands, damaging rice and cotton output.

SPATIAL AND CROP HETEROGENEITY OF IMPACT

- Regions with higher rainfall variability or marginal soils are more exposed to damage.
- Crops like paddy, cotton, pulses, vegetables, and high-value horticulture are particularly vulnerable during flowering or maturity.
- Rainfed areas, smallholders, and regions with weak drainage infrastructure bear disproportionate impact.

ADAPTATION, MITIGATION, AND COPING STRATEGIES

IMPROVED FORECASTING AND EARLY WARNING SYSTEMS

- Agro-meteorological advisories (via IMD, Agricultural Meteorology Division) offering 5-day forecasts of rainfall, temperature, humidity, etc., assist farmers in planning operations.
- Local-level forecasts with spatial resolution (e.g. 9 km, 25 km grids) have helped raise productivity by up to 13% in pilot zones.

Strengthening dissemination (via mobile, SMS, apps) is critical; many farmers still do not receive advisories timely.

CROP DIVERSIFICATION AND RESILIENT VARIETIES

- Cultivating crops less vulnerable to excess moisture or shifting sowing windows helps buffer risk.
- Development and use of climate-resilient, short-duration, water logging-tolerant, disease-resistant varieties can reduce vulnerability.

IMPROVED DRAINAGE, MICRO-IRRIGATION, AND FIELD-LEVEL INFRASTRUCTURE

- Ensuring field drainage and raised beds helps remove excess water quickly.
- Micro-irrigation systems (drip, sprinkler) allow controlled water supply in off-seasons.
- Land leveling, contouring, and soil conservation reduce runoff and erosion.

INSURANCE, CREDIT, AND INSTITUTIONAL SUPPORT

- Weather-indexed crop insurance covering unseasonal rainfall risk can cushion income shocks.
- Timely and subsidized credit, particularly for re-sowing or remedial interventions, helps farmers survive extreme events.
- Extension services must equip farmers with flexible cropping calendars and adaptive management guidance.

CLIMATE-SMART AGRICULTURAL PRACTICES

- Conservation agriculture (minimum tillage, cover crops) improves soil structure and moisture retention.
- Integrated pest and disease management helps manage outbreaks under humid conditions.
- Agro forestry and mixed systems diversify risk.

POLICY AND INSTITUTIONAL MEASURES

- Government disaster relief funds and crop loss compensation schemes must explicitly include unseasonal rainfall events.
- Investments in weather station networks, real-time monitoring, and remote sensing strengthen detection and response.
- Coordination among meteorological, agricultural, water, and disaster management agencies is essential.

CHALLENGES, TRADE-OFFS, AND CONSTRAINTS

DATA, MEASUREMENT, AND ATTRIBUTION

- Identifying and characterizing unseasonal rainfall accurately is complex; distinguishing it from normal variability is nontrivial.
- Linking rainfall deviations explicitly to crop losses requires field-level and high-frequency data, which is often scarce.
- Attribution to climate change vs. natural variability is an ongoing scientific challenge.

HETEROGENEITY IN AGRICULTURAL SYSTEMS

- India's agriculture is highly diverse across agro ecological zones, cropping systems, and resource endowments, making standardized adaptation approaches hard.
- Small and marginal farmers often lack capital, access to technology, or institutional support to respond adaptively.

TIMING AND SCALE OF INTERVENTIONS

- Unseasonal events are often abrupt and localized, making timely response difficult.
- Scaling infrastructure (drainage, forecasting, insurance) across India's vast and varied terrain is costly and logistically challenging.

TRADE-OFFS WITH OTHER POLICY PRIORITIES

- Investment in resilience, infrastructure, and insurance can strain fiscal budgets.
- Overemphasis on one strategy (e.g., diversion to resilient crops) may reduce cropping diversity or local preferences.

ADOPTION AND BEHAVIORAL INERTIA

- Farmers may resist new practices or technologies due to risk aversion, lack of trust, or limited knowledge.
- Institutional delivery gaps (extension, credit, input supply) limit adoption speed.

POLICY IMPLICATIONS AND RECOMMENDATIONS

ENHANCE AND LOCALIZE FORECASTING CAPACITY

- Expand weather station networks, remote sensing systems, and high-resolution models.
- Strengthen the delivery of agro-meteorological advisories via mobile, radio, apps, and local extension, ensuring last-mile reach.

EMBED UNSEASONAL RAINFALL RISK INTO INSURANCE SCHEMES

- Modify crop insurance products to explicitly cover

deviations due to untimely rainfall, not just drought or flood.

- Offer fast claims settlement and re-sowing support within insurance frameworks.

PROMOTE RESILIENT CROP CALENDARS AND VARIETIES

- Encourage shifting planting windows, staggered sowing, and multi-cropping to avoid single-point vulnerabilities.
- Fund breeding programs for water logging-tolerant, disease-resistant, short-duration cultivars.

INVEST IN FIELD-LEVEL INFRASTRUCTURE

- Build drainage channels, contour bunds, raised beds, and field water management systems.
- Strengthen rural roads and storage facilities to reduce post-harvest losses when weather is erratic.

STRENGTHEN INSTITUTIONAL COORDINATION

- Create inter-departmental task forces linking meteorology, agriculture, water resources, and disaster management.
- Use predictive models and climate stress indices to trigger anticipatory relief and support.

CAPACITY-BUILDING AND EXTENSION EDUCATION

- Train farmers in climate-smart practices, adaptive decision-making, and use of advisories.
- Use demonstration plots and participatory research to build trust and learning.

FINANCIAL AND SAFETY-NET INSTRUMENTS

- Provide contingency credit, low-interest loans, and grants to farmers affected by unseasonal rain shocks.
- Strengthen social safety nets (e.g., income support, food security programs) for distressed farming households.

KEY RESEARCH OUTCOMES

The study reveals that unseasonal rainfall is a growing climate risk that significantly affects Indian agriculture.

IMPACT ON CROPPING AND YIELDS

Disruption of Cropping Cycles: Unseasonal rains significantly disrupt traditional cropping cycles and the rhythm of sowing, growing, and harvesting.

Yield Shocks: The combined disruptions lead to sharp yield declines across various crops. Projections suggest rice yield declines of 10-30\% and maize declines of 2-12\% due to precipitation pattern changes.

Post-Harvest Losses: They increase post-harvest losses due to spoilage, sprouting, or pest/disease infestation, especially when rains occur during harvesting.

Damage to Standing Crops: Rainfall during sensitive phases like flowering, grain-filling, or maturation causes damage like lodging, shattering, and sterility.

Planting Disruption: Early excess moisture can delay or hamper land preparation, reduce seed germination, or force farmers to re-sow at sub-optimal timings, reducing crop vigor.

SOCIOECONOMIC AND FARM DISTRESS

Income Losses: Unseasonal rains impose heavy income losses on farmers. Lower yields directly translate into reduced farm income, particularly for small and marginal farmers with limited buffer resources, pushing them into debt and distress.

Increased Risks: The phenomenon raises pest and disease risks by creating humid and moist environments that favor pathogen proliferation (fungi, bacterial blight, mildew) and insect outbreaks.

Cost Escalation: Input losses (e.g., washed-away seeds, leached fertilizers) and the need for more labor for weeding, drainage, and pest control increase farming costs.

Disproportionate Impact: Small and marginal farmers, rainfed areas, and regions with weak drainage infrastructure bear a disproportionate impact.

ENVIRONMENTAL AND CLIMATE LINKS

Soil Degradation: Intense rain events cause surface runoff and soil erosion, stripping topsoil and organic matter, and leading to nutrient leaching (e.g., nitrogen and potassium).

Frequency and Intensity: The study supports that unseasonal rainfall is becoming a more frequent disruption in India's agricultural calendar.

Climate Change Connection: The paper links unseasonal rainfall to anthropogenic climate change, which enhances the moisture-holding capacity of the air, leading to more intense rainfall events.

RECOMMENDATIONS FOR RESILIENCE

The paper concludes by offering concrete recommendations to strengthen the agricultural framework:

Institutional Strengthening: Enhance early warning systems and localized agro-meteorological advisories, ensuring last-mile reach.

Risk Management: Embed unseasonal rainfall risk into crop insurance schemes and provide contingency credit and financial safety nets.

Climate-Resilience: Diversify cropping patterns and promote the use of climate-resilient, water logging-tolerant, and disease-resistant crop varieties.

Infrastructure: Invest in field-level infrastructure, such as drainage channels, raised beds, and improved storage facilities, to reduce water logging and post-harvest losses.

In summary, the research establishes that unseasonal rainfall is no longer a fringe anomaly but a serious, recurrent challenge to India's agricultural stability and farmer livelihoods.

CONCLUSION

Unseasonal rainfall in India represents a growing manifestation of climate risk that tangles itself into multiple dimensions of agricultural vulnerability. In recent years (2023–2025), extreme and untimely rain events have damaged crops, disrupted planting cycles, degraded soils, and inflicted serious income losses on farmers—especially those with limited resources and rainfed systems. The magnitude of these impacts is shaped by timing, intensity, local infrastructure, crop types, and farmers' resilience capacity.

Mitigating these risks demands a holistic response: better forecasting and dissemination, resilient cropping systems, field-level infrastructure, adaptive insurance, and supportive institutions. Policies must shift from reactive compensation to anticipatory resilience. Strengthening extension, financing, and institutional coordination is essential.

In summary, unseasonal rainfall is no longer a fringe anomaly but a present-day challenge to agricultural stability in India. Building resilience to this climate hazard is vital not only for farmer livelihoods, but also for national food security and rural sustainability. Future research should deepen empirical attribution studies, high-resolution modeling of unseasonal rainfall-crop damage links, and evaluation of adaptation interventions to guide evidence-based policymaking.

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