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Climate Change, Agricultural Productivity, and Farmers' Income in India

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Abstract

Climate change presents a multidimensional challenge to Indian agriculture through rising temperatures, variable monsoon rainfall, droughts, floods, heatwaves, and changing pest and disease conditions. These risks can affect crop yields, production costs, marketable output, and the stability of farm-household income. This paper examines the pathways linking climatic conditions, agricultural productivity, and farmers' income in India using a descriptive review and selected secondary statistics from official Indian government sources. The data illustrate two important contexts: India's final foodgrain production estimate for 2023–24 was 332.298 million tonnes, while the National Statistical Office's 2018–19 Situation Assessment Survey reported average monthly income of ₹10,218 per agricultural household. India's annual mean land-surface air temperature in 2024 was 0.65°C above the 1991–2020 average, according to the India Meteorological Department. These indicators describe production, income, and climate conditions separately; they are not a matched dataset and do not establish a causal relationship between climate change and income. The paper discusses heat and rainfall risks, income and cost channels, adaptation options, institutional support, and the data requirements for rigorous quantitative analysis. It concludes that climate-resilient agriculture requires locally appropriate adaptation, improved water management, reliable climate advisories, financial protection, and integrated climate-agriculture-income data.

Keywords: *climate change; agricultural productivity; farmers' income; India; rainfall variability; climate adaptation; foodgrain production; rural livelihoods.*

Introduction

Agriculture is central to India's food system, rural employment, and livelihood security. Agricultural performance depends partly on climatic conditions, including temperature, rainfall timing and intensity, humidity, soil moisture, and water availability. Changes in these conditions can influence sowing decisions, crop development, irrigation needs, pest pressure, and harvesting. Climate-related impacts are not identical across regions: crop type, soil, irrigation infrastructure, farm size, technology, market access, and public support all shape the outcome.

The economic consequences of climate risks extend beyond crop yields. A farmer's net return depends on the quantity and quality of output sold, the price received, the cost of seed and other inputs, labour and irrigation expenses, and losses incurred during storage and transport. A crop failure may reduce sales while increasing replanting or irrigation costs. Conversely, market-price changes can sometimes offset part of a production loss, but they do not necessarily do so for a farmer whose marketable surplus has fallen.

This paper therefore treats climate change, productivity, and income as connected but distinct dimensions. It combines a conceptual review with selected official statistics to establish context and outlines a framework for future empirical analysis. The descriptive statistics are not presented as proof that climate change caused a particular production or income outcome.

Review of Literature

Research on climate and agriculture commonly identifies temperature, precipitation, water availability, and extreme events as important influences on crop growth. Crops have temperature and moisture ranges within which growth is more favourable. Heat during sensitive stages such as flowering or grain filling may reduce yield or quality, while rainfall arriving too early, too late, or in excessive quantities can disrupt agricultural operations.

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Rain-fed agriculture is especially exposed to the timing and distribution of monsoon rainfall. Irrigation can reduce some rainfall-related risks, but it does not eliminate heat stress and may be constrained by groundwater depletion, energy costs, or limited water supplies. Extreme rainfall can damage standing crops and infrastructure, while drought can affect crops, livestock fodder, and rural employment.

The income literature emphasises that agricultural households do not rely solely on crop sales. Their income can include crop and livestock receipts, wages, leasing income, and non-farm business. The Government of India's reporting of the NSO Situation Assessment Survey notes that the average monthly income per agricultural household was ₹10,218 in 2018–19, compared with ₹6,426 in 2012–13. These figures are nominal household-income estimates from separate survey rounds; they should not be interpreted as climate-attributable changes or as a direct measure of crop profit.

Adaptation research identifies climate-resilient varieties, diversified cropping, water conservation, weather information, soil management, crop insurance, agricultural extension, and access to credit as potentially useful responses. Their effectiveness depends on local suitability, affordability, access to markets, implementation quality, and whether support reaches vulnerable farmers.

Objectives of the Study

1. To describe major climate-related risks affecting Indian agriculture.
2. To examine the pathways through which climatic conditions can influence agricultural productivity.
3. To explain how production changes, input costs, and market conditions may affect farmers' income.
4. To present selected official statistics on climate, foodgrain production, and agricultural-household income.
5. To identify adaptation strategies and policy measures for climate-resilient agriculture.
6. To specify data and methods needed for a more rigorous quantitative assessment.

Research Methodology

The study uses a descriptive and analytical secondary-data approach. It draws on selected government statistics and official climate summaries to contextualise the issue, alongside a thematic review of climate-agriculture-income pathways. The selected indicators cover different reference periods and are intentionally reported separately because they do not form a matched panel dataset.

For a causal or correlational assessment, a future study should assemble consistent district- or state-level data for the same years. Required variables would include seasonal temperature, rainfall and anomalies; crop-specific area, production and yield; irrigation; input costs; output prices; and agricultural-household income. A panel regression could include region and year effects and relevant controls. The unit of observation, time period, definitions, missing-data treatment, and limitations should be specified before estimation.

No regression coefficients, correlations, p-values, or effect sizes are invented in this paper. The statistical tables below contain only official figures that can be directly supported by the cited government sources, plus a clearly labelled conceptual framework.

Climate Change and Indian Agriculture

1 Rising temperature and heat stress

Higher temperatures can shorten crop development periods and increase evaporative demand. Heat exposure during crop-specific sensitive stages may reduce grain formation, quality, or yield. The magnitude of any impact depends on crop variety, timing, local climate, soil moisture, and adaptation. The India Meteorological Department reported that India's annual mean land-surface air temperature in 2024 was 0.65°C above the 1991–2020 long-term average, making it the warmest year in the national record beginning in 1901 at the time of that report.

2 Rainfall variability and monsoon dependence

Changes in the timing and distribution of rainfall can affect sowing, crop establishment, irrigation scheduling, and harvest operations. A seasonal rainfall total alone may conceal dry spells or intense rainfall events. Excess rainfall can cause waterlogging, erosion, nutrient loss, and crop damage, while rainfall deficits can create moisture stress, especially in rain-fed regions.

3 Drought, water scarcity, and irrigation

Drought can reduce germination, plant growth, crop yield, and fodder availability. Farmers may respond by purchasing water, operating pumps for longer periods, re-sowing, or changing crops, which can increase costs. Irrigation may provide a buffer against rainfall variability, but it is not a complete safeguard against heat stress and can be unsustainable where groundwater extraction exceeds replenishment.

4 Floods and extreme weather

Floods, intense rainfall, cyclones, and storms can destroy standing crops, damage farm assets, disrupt transport, and affect storage and market access. Repeated events may reduce household savings and increase the time and money required to restore productive capacity.

5 Pests and diseases

Temperature, humidity, and rainfall can alter the distribution and seasonal behaviour of pests, weeds, and crop diseases. These effects are species- and region-specific, and climate is only one of several factors involved. Pest surveillance and locally appropriate integrated pest management are

therefore preferable to assuming a uniform climate effect.

Official Statistical Context

The following tables provide verified descriptive indicators. They should be interpreted as context, not as a direct estimate of the causal effect of climate change on farm income

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Table 1. India's annual temperature and rainfall context, 2024

Indicator	Reported value	Interpretation
Annual mean land-surface air temperature anomaly	+0.65°C relative to 1991–2020 average	2024 was reported as the warmest year in India's national record beginning in 1901.
Annual rainfall over India	104% of the 1971–2020 Long Period Average	An above-average annual total does not rule out regional deficits, dry spells, or damaging heavy-rainfall events.
Southwest monsoon rainfall	108% of the Long Period Average	A national seasonal aggregate can mask substantial regional and temporal variation.

Data Source: *India Meteorological Department (IMD), Annual Climate Summary 2024, issued 15 January 2025: https://internal.imd.gov.in/press_release/20250115_pr_3554.pdf*

Note: Temperature anomaly uses the 1991–2020 reference period; rainfall percentages use the 1971–2020 Long Period Average. These indicators describe one year and do not alone establish a long-term causal impact on agriculture.

Table 2. Final estimates of selected agricultural production indicators, 2022–23 and 2023–24

Crop / group	2022–23	2023–24	Change, approximately
Foodgrains (million tonnes)	329.687	332.298	+0.8%
Rice (million tonnes)	135.755	137.825	+1.5%
Wheat (million tonnes)	110.554	113.292	+2.5%
Pulses (million tonnes)	26.060	24.246	−7.0%
Oilseeds (million tonnes)	41.360	39.669	−4.1%

Data Source: *Government of India, Ministry of Agriculture & Farmers Welfare, Press Information Bureau, "Final Estimates of major agricultural crops for 2023–24," 25 September 2024: https://www.pib.gov.in/PressReleaseIframePage.aspx?PRID=2058534*

Note: Figures are converted from lakh tonnes to million tonnes where needed. Approximate percentage changes are calculated from the reported rounded figures. Production changes may reflect multiple factors; these year-to-year data alone cannot attribute changes to climate change.

Table 3. Average monthly income per agricultural household in India

Survey reference agricultural year	Average monthly income (₹)	Change from previous survey figure
2012–13 (NSO 70th Round)	6,426	—
2018–19 (NSO 77th Round)	10,218	+59.0% nominal increase

Data Source: *Government of India, Press Information Bureau, "Farmers' Monthly Income jumps to Rs. 10,218 in 2018-19 from Rs. 6,426 in 2012-13: NSO Survey," 3 February 2023; based on NSS Reports No. 576 and No. 587: https://www.pib.gov.in/PressReleasePage.aspx?PRID=1896134*

Note: The percentage change is calculated as (10,218 − 6,426) ÷ 6,426 × 100. It is a nominal comparison between survey estimates, not an inflation-adjusted change and not an estimate of climate change's effect. Agricultural-household income includes multiple sources, not crop income alone.

Interpretation of the Statistical Evidence

The official climate summary shows that 2024 was substantially warmer than the 1991–2020 average. This provides evidence of an unusually warm year relative to that reference period. The national rainfall figures were also above the long-period average in aggregate, but national totals do not describe local exposure: one region may experience drought or prolonged dry spells while another receives excessive rainfall.

The final agricultural production estimates show that total foodgrain output rose modestly between

2022–23 and 2023–24, while production of pulses and oilseeds fell. The Ministry of Agriculture's release also noted drought-like conditions in southern states, including Maharashtra, and a prolonged dry spell during August in Rajasthan; it reported that moisture stress affected the production of pulses, coarse cereals, soybean, and cotton. Nevertheless, national production outcomes are influenced by crop area, input use, technology, prices, policy, and weather across multiple regions. The aggregate figures cannot isolate a climate-change effect.

The agricultural-household survey figures show an increase in average monthly income from ₹6,426 in 2012–13 to ₹10,218 in 2018–19 in nominal terms. These figures include wages and other income sources as well as net receipts from crop and animal farming. They are not measured in the same years as the climate and crop-production indicators above, so combining them into a single trend or claiming a direct climate-income relationship would be methodologically unsound.

Taken together, the statistics establish that climate conditions, agricultural output, and household income are important and measurable dimensions of the problem. To determine whether and how climate exposure affects productivity and income, a study needs matched regional and annual data and an appropriate identification strategy.

Climate Change and Agricultural Productivity

Productivity can be measured as crop yield per hectare, output per unit of input, or other efficiency measures. Climate stress can influence yield through heat exposure, water stress, crop damage, and altered pest pressure. It can also influence farmers' decisions about crop choice, sowing date, input use, and the area planted. These behavioural responses may reduce losses in some circumstances, but they can also entail additional costs or lower expected returns.

The distinction between total production and yield is important. Production may rise because more land is planted even if yield per hectare falls. Conversely, production may fall because harvested area contracts after a weather shock. A sound analysis should therefore consider area, production, and yield separately and, where possible, use crop-specific measures.

Climate Change and Farmers' Income

1 Revenue and marketable surplus

When climatic stress reduces output or quality, the quantity available for sale may fall. A price increase may offset some revenue loss for farmers who still have produce to sell, but it may not help households experiencing severe crop failure. Local market integration, storage capacity, transport, and timing of sale affect the final price received.

2 Production costs

Climate variability may raise spending on irrigation, fuel or electricity, replanting, crop protection, labour, and other inputs. Net returns can therefore fall even when gross revenue changes only slightly. Analyses should use a clearly defined income or net-return measure and distinguish paid-out costs from broader economic costs where possible.

3 Debt and vulnerability

Repeated shocks can weaken savings and increase borrowing needs. Small and marginal farmers may have fewer resources to spread risk across crops, seasons, or income sources. Insurance, timely credit, savings, reliable advisories, and well-designed disaster assistance can improve recovery, although actual benefits depend on eligibility, coverage, and implementation.

4 Household income is broader than farm profit

Agricultural households may receive income from crop production, livestock, wages, leasing out land, and non-farm businesses. Researchers should avoid treating total household income, gross crop revenue, and net farm income as interchangeable measures. Their definitions and reference periods must be stated explicitly.

Analytical Framework and Proposed Model

The proposed framework is: climatic exposure (temperature, rainfall variability, drought, flood, and heat) → crop and farm effects (water stress, crop damage, pest pressure, and input needs) → productivity and cost changes → farm revenue, net returns, and household income. Irrigation, crop diversification, technology, insurance, credit, extension services, and market access may moderate these pathways.

Table 4. Proposed variables and measurement approach

Variable category	Suggested measure	Potential official source
Climate exposure	Seasonal temperature anomaly, rainfall totals and deviations, extreme-event indicators	India Meteorological Department
Agricultural productivity	Crop-specific yield per hectare and production	Ministry of Agriculture & Farmers Welfare
Cultivated area	Sown and harvested area by crop	Directorate of Economics & Statistics, Agriculture
Farm costs	Cost of cultivation per hectare or per unit of output	Government cost-of-cultivation reports
Household income	Income by source and total	NSO / MoSPI Situation

	agricultural-household income	Assessment Survey
Adaptation and controls	Irrigation, crop mix, input use, technology, insurance, market access	Agricultural and household surveys, where available

Data Source: *Data Source: Proposed data-source mapping based on the official agencies and datasets identified in the methodology. The table lists variables to collect; it is not a dataset of observed values.*

A possible panel specification for crop productivity is:

$$Yield_{it} = \beta_0 + \beta_1 Temperature_{it} + \beta_2 Rainfall_{it} + \beta_3 Irrigation_{it} + \beta_4 Controls_{it} + \mu_i + \tau_t + \varepsilon_{it}$$

Here, i denotes the district or state and t denotes the year. Region effects (μ_i) account for time-invariant regional characteristics, while year effects (τ_t) account for common annual shocks. The model should be adapted to the data structure and research question. An income model should additionally consider output prices, input costs, crop mix, household characteristics, and non-farm income. Causal claims require stronger identification than a simple correlation and should be justified explicitly.

Adaptation Strategies for Sustainable Agriculture

1 Climate-resilient varieties and crop planning

Crop varieties tolerant of heat, drought, flooding, or salinity can help reduce specific risks where they are suitable for local conditions. Seed and crop choices should reflect local agro-climatic conditions, water availability, crop duration, market demand, and farmer preferences.

2 Efficient irrigation and water conservation

Drip and sprinkler irrigation, rainwater harvesting, farm ponds, watershed development, soil-moisture conservation, and groundwater management can improve water-use efficiency. Infrastructure support should be combined with maintenance and sustainable management of shared water resources.

3 Diversification and mixed livelihoods

Diversifying crops and, where appropriate, integrating livestock, horticulture, or other livelihood activities may reduce dependence on a single source of revenue. Diversification is not automatically profitable: suitable markets, storage, processing, extension support, and access to finance are important.

4 Weather information and extension

Timely local-language forecasts and actionable advisories can support decisions about sowing, irrigation, fertiliser use, pest management, and harvesting. Agricultural extension institutions and farmer organisations can help translate forecasts into locally relevant actions.

5 Insurance, credit, and social protection

Crop insurance and suitable credit can help eligible farmers manage some financial shocks. The usefulness of these measures depends on understandable terms, appropriate risk coverage, accessible enrolment, timely assessment, and claim settlement. Emergency assistance should be coordinated with longer-term resilience planning.

6 Soil health and sustainable farming

Soil testing, balanced nutrient management, organic matter improvement, erosion control, mulching, and conservation practices can support soil structure and water retention. The benefits and costs should be assessed under local conditions rather than assuming that a single practice is appropriate everywhere.

Government and Institutional Support

Public investment in agricultural research, irrigation, watershed development, climate information, rural roads, storage, market infrastructure, and extension can strengthen resilience. Agricultural policy should integrate climate risk into district and state planning and prioritise farmers with limited access to water, credit, insurance, technology, and reliable markets.

Monitoring should focus on measurable outcomes such as yield stability, water-use efficiency, net returns, insurance claim timelines, and recovery after extreme events. Programme evaluation should account for differences in climate exposure and farm characteristics and should not infer success solely from the number of beneficiaries or inputs distributed.

Limitations

- The selected official statistics refer to different periods and units of analysis; they are not a matched climate-agriculture-income dataset.
- National annual averages can conceal important regional and seasonal differences.
- Household income includes multiple income sources and is not equivalent to net crop income.
- Year-to-year changes in agricultural production may reflect area, technology, inputs, prices, policy, and weather; the descriptive figures do not isolate climate change.
- A rigorous causal assessment would require consistent data, explicit model specification, diagnostic testing, and a defensible identification strategy.

Recommendations

1. Develop locally tailored climate-resilient crop and seed strategies.
2. Improve irrigation efficiency, rainwater harvesting, watershed management, and sustainable groundwater use.

3. Expand timely, local-language weather advisories and strengthen agricultural extension.
4. Promote feasible crop and livelihood diversification with market and storage support.
5. Improve access to insurance, institutional credit, and disaster recovery support, particularly for small and marginal farmers.
6. Integrate climate, crop-yield, cultivation-cost, price, and household-income datasets at district and annual levels.
7. Report data definitions, reference periods, sources, and uncertainty transparently beneath every table.
8. Evaluate adaptation programmes using yield stability, net returns, costs, water-use efficiency, and recovery indicators.

Conclusion

Climate change poses material risks to Indian agriculture through temperature rise, rainfall variability, drought, floods, heatwaves, and changes in pest and disease conditions. These risks can affect crop productivity and farmers' income through changes in yields, quality, input costs, marketable surplus, and recovery expenses. The effects differ across regions and farm households and depend on irrigation, crop choices, technology, market access, and institutional support.

The official statistics presented here provide useful context: IMD reported that 2024 was 0.65°C warmer than India's 1991–2020 average; final foodgrain production was estimated at 332.298 million tonnes in 2023–24; and the NSO's 2018–19 survey reported average monthly agricultural-household income of ₹10,218. These figures measure distinct phenomena and do not, by themselves, establish a causal climate-income relationship.

A stronger empirical assessment should combine climate observations with crop-specific productivity, costs, prices, and household-income data for matching regions and years. Climate-resilient varieties, efficient water management, diversification, weather advisories, financial protection, research, and institutional coordination are important components of adaptation. Evidence-based and locally appropriate interventions can help reduce climate risk and strengthen the long-term resilience of Indian farmers.

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Conflicts of interest

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