International Journal of Social Science and Education Research

ISSN Print: 2664-9845
ISSN Online: 2664-9853
Impact Factor: RJIF 8.42
IJSSER 2025; 7(2): 470-472
www.socialsciencejournals.net
Received: 14-06-2025
Accepted: 17-07-2025

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Climate Change Impacts on Indian Agriculture

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DOI: https://doi.org/10.33545/26649845.2025.v7.i2f.380

Abstract
Climate change presents a serious threat to Indian agriculture, a vital sector that supports the livelihoods of about half the population and plays a major role in the national economy. This paper compiles recent research and secondary data to examine how increasing temperatures, altered rainfall patterns, extreme weather events, and rising sea levels impact crop production, water supply, soil health, pest behavior, and the capacity of communities to withstand economic and social challenges. The study looks at different regions in India, such as the Indo-Gangetic Plains, the southern peninsular area, the eastern and northeastern rain-fed regions, and coastal areas, to understand their unique vulnerabilities. It also suggests various ways to adapt, including technological, governance, and environmental strategies. The paper recommends policies that support climate-resilient farming through targeted investment, enhanced governance, and programs that benefit small-scale farmers. It also notes the current limits of available research and suggests where future studies should focus.

Keywords: Climate, Agriculture, Temperature, Monsoon, Droughts

Introduction
Agriculture in India is highly affected by changes in the climate. The reliance on monsoon rains, the high number of small farms that depend on rain, and limited access to financial resources make the sector vulnerable to both slow climate changes and sudden weather events. Reports by the Intergovernmental Panel on Climate Change (IPCC) and national studies point out that South Asia, including India, faces greater risks. Forecasts suggest that rising temperatures, changes in monsoon patterns, and more frequent heatwaves, floods, and droughts could lower yields for many important crops and create new problems for food supply, rural livelihoods, and the agricultural economy.

Literature Review
A lot of the recent research has examined how climate change affects Indian agriculture. Field studies and model predictions show that wheat and rice production are especially sensitive to higher temperatures during key growth stages, while millets and some legumes are more tolerant. Research also shows that the effects vary by region: for instance, the Indo-Gangetic Plains may see reduced wheat yields in a warmer future, while southern areas might need to adjust planting times and use more irrigation. The studies also highlight how issues like soil decline, overuse of groundwater, and changes in pests and diseases increase climate risks. Social and economic studies show that small farmers, women, and disadvantaged groups have less capacity to adapt, so safety nets and access to loans are important for building resilience.

Methodology and Data Sources
This paper summarizes information from existing studies and reports, including academic articles, national documents like those from the Indian Council of Agricultural Research and the Ministry of Agriculture, international assessments such as those from the IPCC and FAO, and relevant government policies.
Important trends and data are drawn from published analyses and official statistics on crop production, rainfall, and groundwater levels. The analysis uses insights from spatial studies to identify regions at higher risk and to provide examples of how different areas are affected.

Impacts on Physical Systems

Temperature Rise and Crop Physiology

Rising temperatures affect crops in ways that impact their development and final yield.

Higher temperatures can speed up growth stages, shorten the time for grain filling, and reduce overall production. Excessively high nighttime temperatures can lower the quality of rice and decrease wheat yields. Heat stress during flowering and the grain-filling stages can lead to large drops in crop output. Experimental studies and models have estimated how much yields could fall under different climate scenarios, showing how sensitive key crops are to temperature changes.

Precipitation Variability and Monsoon Shifts

Changes in the timing and intensity of monsoons, along with unpredictable rainfall, can mess up planting schedules, increase the chance of crop failure, and cause soil erosion.

Rain-fed farming, which covers a large part of India's farmland, is especially at risk. Variability in rainfall also affects how much water flows on the surface and how much water is absorbed into the ground, which in turn influences water availability.

Extreme Events: Floods, Droughts, and Cyclones

The number and strength of extreme weather events like droughts, floods, and cyclones have gone up in recent years, leading to short-term crop loss and long-term harm to land productivity. Coastal farming areas are at risk from cyclones and rising sea levels, which can lead to saltwater entering farming areas and reducing the land available for crops. Floods harm soil structure and nutrient levels, while droughts reduce soil moisture and hinder seed germination and crop growth.

Soil Health and Pest Dynamics

Climate-related changes affect how much moisture is in the soil and how quickly organic matter decomposes, which influences nutrient availability. Warmer temperatures and changing humidity levels can allow more pests and diseases to spread, introducing new challenges where farmers might not have effective ways to manage them.

Regional Vulnerability Analysis

Indo-Gangetic Plains (IGP)

The Indo-Gangetic Plains, a major food-producing region, face heat stress during the wheat season and water shortages due to heavy use of groundwater for irrigation. Reduced wheat yields under warming scenarios are a serious concern, with potential impacts on food prices and rural incomes.

Western and Central India

In the western and central parts of India, dry areas are experiencing more frequent droughts.

The reliance on rain-fed farming and limited irrigation systems makes these areas sensitive to unpredictable monsoon rainfall, posing a threat to regular crop production.

Eastern and North-Eastern India

Eastern India, including parts of Bihar, West Bengal, and Odisha, is exposed to flooding and cyclones in coastal regions. Traditional farming practices and planting schedules are being disrupted, and new strategies are needed to help farmers grow crops that can withstand flooding.

Southern Peninsular and Coastal Regions

In peninsular India, shifting growing seasons and higher irrigation needs are expected. Coastal areas face increasing salinization of water and soil due to rising sea levels and storm surges. This affects rice and other crops grown in low-lying areas and increases the risk from cyclones and sea-level rise.

Case Studies

Case Study 1: Punjab and Haryana: Groundwater and Heat Stress

Punjab and Haryana, which are leading producers of cereals under the Green Revolution, depend heavily on groundwater for irrigation. Long-term overuse of groundwater and rising temperatures have led to falling water levels and higher costs for pumping water. Heat stress during the wheat-growing season has contributed to observed yield plateaus and occasional declines.

Case Study 2: Eastern India: Flood-prone Rice Systems

In eastern India, frequent flooding and cyclones damage rice crops, delay planting, and result in losses after harvest. Although traditional flood-resistant rice varieties and raised-bed farming have shown some success, there is a lack of comprehensive support for seed availability and farming advice.

Case Study 3: Coastal Andhra Pradesh and Tamil Nadu: Saline Intrusion and Coastal Erosion

Coastal regions have seen an increase in saltwater intrusion into groundwater and soil due to rising sea levels and storm surges. This hampers rice farming and has led some farmers to switch to salt-tolerant crops or aquaculture, with varied effects on local communities.

Socioeconomic Impacts

Climate-related challenges lead to financial losses, unstable food prices, and greater risk for small-scale farmers. Loss of income from failed crops can result in debt, forced migration, and worsening food shortages. Women farmers and landless workers are especially at risk because they often have fewer assets and limited access to information and financial support.

Adaptation Strategies

Agronomic and Technological Measures

Using climate-resilient seeds that can withstand drought, heat, and floods, along with improved farming techniques like conservation farming, crop variety diversification, and precise nutrient management, can help reduce the risks faced by farmers. Efficient water use, such as micro-irrigation, is crucial in areas with limited water supply.

Ecosystem-based Adaptation

Practices like agroforestry, restoring wetlands, and improving soil health can boost natural services, increase carbon storage, and ease local climate conditions. These strategies also offer additional income sources for rural families.

Institutional, Financial, and Policy Measures

Improving agricultural advice, better access to climate and weather information, and creating insurance programs that cover climate-related risks are important. Policies that

encourage water conservation and efficient use, as well as reforms in land and water management to ensure fair access, are also key.

Community-based and Social Measures

Adapting through community-led efforts, farmer groups, and methods that combine local knowledge with scientific advice can increase the adoption of climate-resilient practices.

Supporting women and marginalized groups through education and financial support can raise overall resilience.

Policy Recommendations

1. Increase investment in research and sharing of climate-resilient crops and farming methods suited to specific areas.
2. Expand micro-irrigation, rainwater collection, and managed groundwater recharge projects with community involvement.
3. Improve groundwater management by encouraging sustainable use through pricing policies, subsidies for efficient equipment, and stronger regulations.
4. Strengthen early warning systems and provide climate-related advice to farmers, using mobile platforms and seasonal forecasts.
5. Revise crop insurance plans to cover multiple climate risks and ensure quick compensation.
6. Develop programs to support alternative income sources, such as processing agricultural products and non-farming jobs in rural areas.
7. Create policies that consider gender, ensuring women have access to resources, information, and opportunities to contribute to decisions.

Research Gaps and Future Directions

Although there has been notable progress, there are still gaps in high-quality climate impact predictions for local planning, long-term evaluations of new crop varieties in different farming environments, and assessments that include both environmental and social factors.

Future studies should focus on research that connects farm-level actions to broader food system resilience, examines the role of markets and supply chains in adaptation, and assesses the real-world effectiveness of policies.

Limitations

This report is based on existing sources and does not present new field data. While it draws on peer-reviewed studies and national reports, differences in research methods across sources make it difficult to make accurate numerical predictions. Nonetheless, the qualitative analysis provides useful guidance for policymakers and researchers.

Conclusion

Climate change poses a threat to agricultural productivity, sustainability, and rural livelihoods in India. The effects vary across regions and are influenced by pre-existing challenges such as overuse of groundwater, soil degradation, and social and economic inequality. Effective adaptation requires a combination of technological, ecological, institutional, and social approaches. Policy action, research funding, and inclusive governance are essential to create resilient agricultural systems that support food security and rural communities.

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