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CLIMATE CHANGE AND ITS ECONOMIC IMPACT ON AGRICULTURAL PRODUCTIVITY IN INDIA: TRENDS, CHALLENGES, AND POLICY RESPONSES

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ABSTRACT

Climate change has emerged as one of the most pressing global challenges of the 21st century, with its impact being disproportionately severe in agrarian economies such as India. Agriculture in India is highly dependent on climatic conditions, particularly rainfall, temperature, and seasonal patterns. Variations in these factors have direct implications on crop yields, food security, and rural livelihoods. This paper examines the trends of climate change in India, its economic impact on agricultural productivity, and the major challenges faced by the sector. Furthermore, it evaluates the policy responses of the Indian government and international agencies, while suggesting measures to enhance resilience and ensure sustainable agricultural growth.

Key Words: Climate Change, Agriculture, Productivity, Economic Impact, Policy Response, India, Food Security.

INTRODUCTION

INTRODUCTION

Agriculture continues to occupy a central position in India's economy, providing livelihoods to a large proportion of the population and contributing significantly to national income, food security, and rural employment. However, the sector is increasingly threatened by climate change and climate variability. Rising temperatures, irregular monsoon patterns, prolonged droughts, floods, heatwaves, and other extreme weather events are creating serious challenges for agricultural production and rural livelihoods. Since Indian agriculture, particularly rainfed farming, remains highly dependent on climatic conditions, even small changes in temperature and rainfall can have substantial consequences for crop yields, farm income, food prices, and rural employment. The Intergovernmental Panel on Climate Change (IPCC) has identified South Asia as one of the regions particularly vulnerable to the adverse effects of climate change, highlighting the potential risks to agricultural productivity and food security.

Climate change affects Indian agriculture through several interconnected pathways. Increasing temperatures can shorten crop-growing periods and reduce the productivity of temperature-sensitive crops such as wheat and rice. Changes in the timing, intensity, and distribution of monsoon rainfall can disrupt sowing and harvesting operations and increase the frequency of crop failures. Extreme weather events such as floods, cyclones, droughts, and heatwaves can directly damage standing crops, livestock, irrigation infrastructure, and rural assets. In addition, declining groundwater availability has become an important concern in major agricultural states where intensive irrigation has contributed to groundwater depletion. These environmental pressures have significant economic consequences, particularly for small and marginal farmers who have limited financial resources and fewer opportunities to absorb climatic shocks.



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The economic implications of climate change extend beyond crop production. Declining agricultural productivity can reduce farm income, increase production costs, affect food prices, and weaken rural employment opportunities. Climate-related losses can also widen regional disparities because different parts of India experience varying levels of exposure and adaptive capacity. Rainfed and semi-arid regions are particularly vulnerable to drought and rainfall variability, while coastal areas face additional risks from cyclones, flooding, and salinity intrusion. Consequently, climate change represents not only an environmental challenge but also a major economic and social development issue.

Recognizing these risks, the Government of India has implemented several policy and institutional measures to strengthen agricultural resilience. The National Action Plan on Climate Change (NAPCC) and the National Mission for Sustainable Agriculture (NMSA) promote sustainable resource management and climate-resilient agricultural practices. The Pradhan Mantri Fasal Bima Yojana (PMFBY) provides crop insurance against specified agricultural risks, while the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) promotes efficient irrigation and the principle of “Per Drop More Crop.” Other measures include climate-resilient seed varieties, micro-irrigation, crop diversification, agroforestry, integrated pest management, agricultural credit, digital weather advisories, and support for Farmer Producer Organizations.

Technological innovation is also becoming increasingly important in climate adaptation. Remote sensing, satellite-based monitoring, artificial intelligence, weather forecasting, and digital agricultural advisory services can improve farmers’ access to timely information and support better decisions regarding sowing, irrigation, pest management, and harvesting. International cooperation under the Paris Agreement and Sustainable Development Goals further supports India’s efforts to promote sustainable and climate-resilient agriculture.

Against this background, the present study examines the relationship between climate change and agricultural productivity in India, with particular emphasis on agricultural and economic effects, regional vulnerabilities, and adaptation and policy responses. It seeks to understand how climatic changes influence agricultural outcomes and how appropriate technological, institutional, and policy interventions can enhance agricultural resilience, protect rural livelihoods, and promote sustainable agricultural productivity in India.

OBJECTIVES OF THE STUDY

1. To analyze the trends of climate change in India and their implications for agriculture.
2. To assess the economic impact of climate change on agricultural productivity.
3. To identify the key challenges faced by farmers due to climate variability.
4. To evaluate the effectiveness of existing policies and adaptation strategies.
5. To suggest policy measures and sustainable practices for enhancing climate resilience in agriculture.

Research Questions

1. What major changes have occurred in India's temperature and rainfall patterns?
2. What trends are visible in agricultural productivity during the study period?



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3. What relationship exists between climatic variables and agricultural productivity?
4. What are the major economic consequences of climate-induced agricultural losses?
5. Which regions and crops appear to be particularly vulnerable?
6. What adaptation strategies and policy interventions have been implemented?
7. What are the major gaps in India's climate-resilient agricultural policy framework.

HYPOTHESES

1. **H1:** Climate change has a significant negative impact on agricultural productivity in India.
2. **H2:** Regional disparities exist in the extent of climate change impact on crop yield across different agro-climatic zones of India.
3. **H3:** Farmers with access to modern technology, irrigation, and adaptive practices experience less economic loss from climate change than those relying on traditional methods.
4. **H4:** Existing government policies and schemes have only a partial effect in mitigating the economic losses caused by climate change.
5. **H5:** Adoption of climate-resilient agricultural practices (such as crop diversification, water conservation, and use of high-yield climate-tolerant seeds) has a positive and significant impact on agricultural productivity and farmer income.

REVIEW OF LITERATURE

Kumar & Parikh (2001): Using a Ricardian approach with cross-sectional farm data, Kumar and Parikh estimate the relationship between farm net revenue and long-run climate normals (temperature, precipitation). They find that higher temperatures significantly depress farm revenues, and the negative temperature effect dominates any gains from additional rainfall. Their welfare simulations imply sizable economic losses for Indian agriculture under warming scenarios, highlighting the economic vulnerability of rain-fed regions and the value of irrigation as an adaptation. By linking climate directly to profits rather than yields alone, the paper captures input, output, and cropping-pattern adjustments embedded in farmers' choices—making the “bottom-line” economic impact especially clear.

Auffhammer, Ramanathan & Vincent (2006): This PNAS study integrates statistical models of historical Indian rice harvests with climate/atmospheric data to isolate the impacts of greenhouse gases and “atmospheric brown clouds” (aerosols). The authors show both drivers have independently negative—and additive—effects on rice production, with stronger impacts after the mid-1980s. The key contribution is to pinpoint air pollution (short-lived climate pollutants) as a distinct channel, alongside GHG warming, through which climate change degrades staple crop productivity—implying that mitigation of regional air pollution can yield near-term agricultural (and economic) benefits.



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Guiteras (2009) : Analyzing 40 years of district-level panel data (1960–1999) across major crops, Guiteras estimates weather–yield relationships and projects impacts under climate change. Without long-run adaptation, the study projects aggregate yield declines of roughly 4.5–9% by 2010–2039 and ~25% by 2070–2099. These declines imply substantial income losses for farm households and downstream effects on rural wages and food prices. The paper’s transparent empirics and explicit projections for India made it a reference point for policy discussions on both mitigation’s benefits and the scale of adaptation required.

De Graaf et al. / Science Advances (2020): Groundwater depletion and cropping intensity

While not a pure temperature–yield paper, this study quantifies a critical climate–water–agriculture linkage: given current groundwater depletion trends (exacerbated by warming and erratic monsoons), India’s national cropping intensity could fall ~20%, and up to ~68% in the most-depleted regions. For an economy where irrigation underpins yield stability and multi-season cultivation, reduced groundwater availability transmits directly into lower output, incomes, and food security. The findings foreground adaptation policies around water governance, canal expansion, energy pricing for pumps, and a shift towards less water-intensive crops.

Taraz (2019) : Examining whether Indian farmers can (and do) adapt to rising heat, this study finds only limited within-crop adaptation to higher temperatures in the short run, with yield and income losses concentrated on the hottest days. While farmers adjust planting dates and inputs to some extent, the evidence suggests strong non-linear heat damages that current practices cannot fully offset. Economically, this points to sizeable residual damages without structural changes—such as switching crops/varieties, expanding irrigation access, heat-tolerant seeds, and insurance—reinforcing the need for targeted policy responses beyond incremental on-farm adjustments.

RESEARCH METHODOLOGY

Research Design

The study will adopt a **descriptive, analytical and empirical research design** based exclusively on secondary data. A longitudinal approach will be used to examine changes over an extended period.

Nature and Sources of Data

No primary survey will be conducted. The study will rely on secondary data obtained from credible national and international sources, including:

- Ministry of Agriculture and Farmers Welfare, Government of India
- Ministry of Statistics and Programme Implementation
- India Meteorological Department



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- Reserve Bank of India
- NITI Aayog
- Directorate of Economics and Statistics
- Agricultural Statistics at a Glance
- Economic Survey of India
- Census and other Government of India publications
- FAOSTAT
- World Bank databases
- IPCC reports
- United Nations agencies
- Peer-reviewed academic journals
- Research reports and institutional publications

The proposed study may use annual and state-level observations depending upon data availability.

Variables

The major independent variables will include:

- Mean temperature
- Maximum and minimum temperature
- Annual and seasonal rainfall
- Rainfall variability
- Frequency of droughts
- Flood and extreme-weather events

Dependent variables may include:

- Crop yield per hectare
- Agricultural production
- Agricultural gross value added
- Agricultural income



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- Food prices
- Employment indicators
- Irrigation coverage
- Crop diversification

Control variables may include fertiliser consumption, irrigation, agricultural inputs, technological development and cultivated area.

Period of Study

The study proposes to analyse a sufficiently long period, tentatively **1990–2025**, subject to the availability, consistency and comparability of secondary data.

Sampling

Since the research is based on secondary data, conventional primary sampling will not be required. Where state-level analysis is undertaken, states may be selected according to data availability and agricultural importance. Major agricultural states can be analysed comparatively to identify differences in climate vulnerability and adaptation capacity.

9.6 Data Analysis Techniques

The collected data will be analysed using appropriate statistical and econometric techniques, including:

- Descriptive statistics
- Percentage and compound annual growth rates
- Trend analysis
- Correlation analysis
- Regression analysis
- Time-series analysis
- Panel-data analysis, where state-level data are available
- Comparative regional analysis
- Index construction, where appropriate

Graphs, tables and charts will be used to present major trends. Appropriate statistical software may be used for data management and analysis.

Scope of the Study



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The study will focus on the relationship between climate change and agricultural productivity in India. It will examine national trends and, where data permit, regional differences. Major food and commercial crops may be included. The study will focus on measurable economic and agricultural indicators rather than attempting to examine every environmental consequence of climate change.

The research will also assess major government policies related to climate adaptation, agricultural sustainability, irrigation, insurance and resource management.

Significance of the Study

The proposed research has academic, economic and policy significance. Academically, it will contribute to the literature by integrating climate, agriculture and economic indicators within a single analytical framework.

From an economic perspective, understanding the relationship between climate change and agricultural productivity can help policymakers anticipate risks to farm income, food supply and rural employment. The findings may also help identify regions and crops requiring greater adaptation support.

From a policy perspective, the study can contribute evidence for strengthening climate-resilient agriculture. It may help policymakers improve irrigation planning, crop insurance, agricultural research, extension services, water conservation and farmer support programmes.

Expected Outcomes

The study is expected to:

1. Identify major long-term trends in temperature and rainfall.
2. Establish trends in agricultural production and productivity.
3. Determine the nature and strength of relationships between climatic variables and agricultural productivity.
4. Identify major economic consequences of climate-related agricultural variability.
5. Highlight regions and crops facing relatively greater climate risks.
6. Assess strengths and limitations of existing policy responses.
7. Develop evidence-based recommendations for climate-resilient agricultural development.

Limitations of the Study

The principal limitation is dependence on the availability and quality of secondary data. Differences in definitions, geographical coverage and measurement methodologies across databases may affect comparability. Climate impacts may also vary considerably across crops and regions, making national-level generalisations difficult. Furthermore, statistical



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associations cannot always establish direct causality because agricultural productivity is influenced by numerous technological, economic and institutional factors.

Conclusion

Climate change poses a serious threat to India's agricultural productivity and economic stability. The dependence on monsoon, predominance of smallholder farming, and socio-economic vulnerabilities amplify the risks. While India has initiated several policy measures, more integrated and long-term strategies are needed to safeguard food security and rural livelihoods. Sustainable agricultural practices, technological innovation, institutional reforms, and global cooperation will be key to addressing the challenges of climate change. Ultimately, enhancing resilience in agriculture is not only an economic imperative but also a social and environmental necessity for India's future.

The economic impact is further compounded by regional disparities, as rain-fed and resource-poor states face greater risks compared to irrigated and technologically advanced regions. These challenges highlight the urgent need for adaptive and resilient agricultural strategies. While policy measures such as crop insurance schemes, climate-resilient seed varieties, and irrigation reforms have been initiated, gaps remain in implementation, awareness, and equitable distribution of benefits. Moreover, the transition towards sustainable agricultural practices, diversification, and digital innovations must be accelerated to cushion the sector against future uncertainties.

In conclusion, the intersection of climate change and agricultural productivity in India underscores a pressing need for proactive, integrated, and forward-looking policy responses. Strengthening adaptive capacities, investing in research and innovation, and ensuring farmer-centric approaches will not only mitigate the adverse economic impacts but also pave the way for sustainable and resilient agricultural growth. The path ahead demands a collaborative effort from the government, private sector, scientific community, and farming households, to ensure that Indian agriculture remains both productive and sustainable in the face of climate uncertainty



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