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Climate change's effects on Indian food security via climate-smart agriculture

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Abstract

In this research paper, we explore the impact of climate change on food security in India and examine the role of Climate-Smart Agriculture (CSA) in mitigating these effects. India is especially susceptible to climate-related issues, such as rising temperatures, unpredictable rainfall, and an increase in the frequency of extreme weather events, because of its extensive agricultural sector. Crop yields have significantly decreased as a result of these causes, especially in important agricultural areas like Punjab, Bihar, Madhya Pradesh, and Odisha.

Using a mixed-methods approach, primary data was collected from 200 farmers across these regions through surveys and interviews, while secondary data on climate trends and agricultural productivity was analyzed. The results show a clear correlation between climate change and reduced agricultural output, with rice and wheat being the most affected crops. The study also found that CSA practices, such as water-efficient irrigation systems and crop diversification, enhance resilience to climate variability, although their adoption remains uneven across regions.

The paper concludes by emphasizing the need for expanded adoption of CSA practices through government support, financial aid, and farmer education. By integrating CSA into broader agricultural policies, India can improve its food security and ensure a sustainable agricultural future in the face of climate change.

Key Words: Climate Change, Food Security, Crop Yields, Sustainable Agriculture, Climate Adaptation, Farmer Resilience, Agricultural Productivity, Water-Efficient Irrigation, Crop Diversification.

Introduction

Climate change poses a huge danger to global food security, with the consequences being especially severe in developing countries such as India. As a country where agriculture employs over 42% of the workforce and accounts for 17-18% of GDP, India is extremely vulnerable to climatic changes. The Intergovernmental Panel on Climate Change (IPCC) estimates that agricultural yields could be reduced by up to 25% by 2050 due to climate change, which would have a substantial impact on food production. With a population of over 1.4 billion, India must balance environmental constraints with the need to provide food security.

Major crops like rice, wheat, and maize—all essential to India's food security—are already feeling the effects of rising temperatures, erratic monsoon patterns, a rise in the frequency of droughts, and floods. The Indian Council of Agricultural Research (ICAR) estimates that under harsh weather, rice yields could drop by 15% and wheat productivity could decrease by 6–10% for every degree Celsius that the temperature rises. The livelihoods of millions of smallholder farmers who depend on agriculture are also at risk due to these developments, in addition to the food supply.

Climate-Smart Agriculture (CSA) seems to be a viable solution to these emerging problems. In order to mitigate the adverse consequences of climate change, CSA integrates climate resilience with sustainable farming practices. The National Mission for Sustainable Agriculture (NMSA) of the Indian government actively supports CSA by implementing climate-resilient crop varieties, agroforestry, and improved water efficiency. Although CSA has demonstrated potential, its application is still restricted to particular areas, highlighting the need for a more thorough set of regulations and support networks.

Objectives

1. *To analyze the effects of climate change on food security in India.*
2. *To assess the part that climate-smart agriculture (CSA) plays in reducing these effects.*

Overview of Climate Change

Rising temperatures, changing weather patterns, and an increase in the frequency of extreme weather events like storms, floods, and droughts are all signs of climate change, a worldwide phenomenon. The accumulation of greenhouse gases (GHGs) in the atmosphere, mainly carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O), brought on by human activities including the burning of fossil fuels, deforestation, and industrial agriculture, is the primary cause of climate change. The United Nations reports that the last decade (2011–2020) was the warmest on record and that the average global surface temperature has increased by roughly 1.2°C since the late nineteenth century (Bolan, S. et. al. 2024).

Climate change has far-reaching consequences worldwide. Rising sea levels endanger coastal areas, while shifting precipitation patterns impact water availability and agriculture, particularly in developing countries. According to the World Bank, over 100 million people may be forced into extreme poverty by 2030 as a result of climate change. Furthermore, climate change is intensifying food and water insecurity, raising the likelihood of displacement, and reducing biodiversity. Urgent global cooperation and sustainable practices are required to alleviate these effects and ensure future resilience.

Figure 1: Climate Change

Review Literature

1. ***Kumar M. et. al. (2024).*** -This article discusses various strategies for enhancing agricultural resilience in the face of climate change. The authors focus on the importance of adopting sustainable practices that increase the resilience of farming systems to climate stressors such as extreme weather conditions, temperature fluctuations, and water scarcity. Through an analysis of climate change models and field case studies, they explore how farmers can use resource-efficient technologies, crop diversification, and improved irrigation systems to cope with climate change. The paper emphasizes that building resilience is not just about technological solutions but also involves policy interventions, extension services, and farmer awareness programs. This reference is valuable for understanding the broader context of climate adaptation strategies in agriculture (Kumar, M., Boruah, A., Sonia, H., & Padha, K. 2024).
2. ***Singh, M. et. al. (2023).*** -In this article, Singh and Hasan explore the significance of Climate-Smart Agriculture (CSA) in the Indian context. They review the adoption of CSA practices across various regions in India, focusing on water conservation techniques, soil fertility management, and the introduction of drought-resistant crop varieties. The authors stress that CSA offers a sustainable pathway to ensure food security in the face of climate variability. They also highlight the challenges that farmers face in adopting CSA, such as high costs, lack of knowledge, and insufficient government support. This paper provides critical insights into the effectiveness and limitations of CSA in improving agricultural productivity and mitigating climate-related risks in India (Singh, M., & Hasan, F. Q. 2023).
3. ***Balasundram et al. (2023).*** In order to ensure food security and lessen the effects of climate change on agriculture, this study explores the potential of digital agriculture. They look at a variety of digital solutions that assist farmers in making data-driven decisions to maximize resource use, boost yields, and lessen their impact on the environment, including machine learning, remote sensing, and precision farming. The authors contend that by offering crop health monitoring, real-time meteorological data, and early warnings for climate-related hazards, digital agriculture improves the effectiveness of CSA operations. Understanding the relationship between technology and climate adaptation in agriculture is made easier by this article, which shows how advancements in digital tools can help farmers deal with climatic concerns (Balasundram, S. K., Shamshiri, R. R., Sridhara, S., & Rizan, N. 2023).
4. ***Arjoo, Kumar et. al. (2022).*** - This essay looks at how urgently CSA practices must be put into place in order to address the escalating problems caused by climate change. The authors examine several CSA practices, such as conservation tillage, agroforestry, and the adoption of climate-resilient crop types. They go over how these methods can improve crop resistance to harsh weather conditions, preserve soil health, and save water. The essay also discusses the obstacles that prevent CSA from being widely adopted, including lack of awareness, budgetary limitations, and insufficient policy backing. In order to guarantee agriculture's long-term sustainability in the face of climate change, the authors urge more

extensive policy frameworks and investments in CSA. This source gives a concise summary of the state of CSA today and highlights how important it is to attaining sustainable food production (Arjoo, Kumar, V., & Shreya. 2022).

Methodology

In order to evaluate the impact of climate change on Indian food security and the function of Climate-Smart Agriculture (CSA), this study uses a mixed-methods approach, integrating qualitative and quantitative data collection methodologies.

Data Collection

1. **Primary Data**:
   - Surveys and structured interviews with 200 farmers from climate-vulnerable regions of India, including Punjab, Madhya Pradesh, Bihar, and Odisha. These regions were selected based on their varying climatic conditions and dependence on agriculture.
   - Interviews with agricultural experts, policymakers, and local government officials to understand CSA adoption and policy impact.
2. **Secondary Data**:
   - Analysis of historical climate data from the India Meteorological Department (IMD), focusing on temperature, rainfall, and extreme weather events over the last 20 years.
   - Agricultural productivity data sourced from government reports, including the National Sample Survey Office (NSSO) and the Indian Council of Agricultural Research (ICAR), to measure the impact of climate change on crop yields.

Results

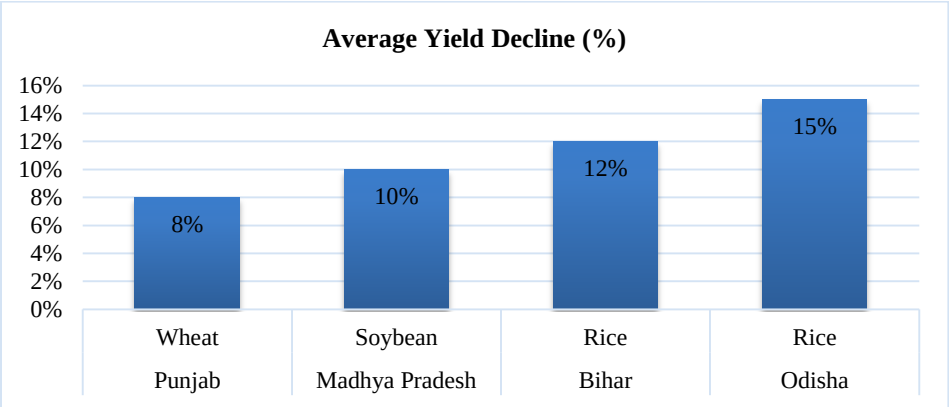
The results of this study offer a thorough analysis of how climate change affects food security in India and how well Climate-Smart Agriculture (CSA) works to mitigate these consequences. With a focus on important factors including crop production variances, farmer attitudes toward climate change, and the regional spread of CSA practices, the conclusions are supported by both primary and secondary data.

1. Impact of Climate Change on Crop Yields

Climate change caused agricultural production fluctuation, according to farmer data. Punjabi wheat farmers have reported a decade-long decline in yield due to rising temperatures and inconsistent rainfall. Rice production in Bihar and Odisha has been affected by erratic monsoon patterns and flooding (Hussain, Y. 2024).

Table 1 summarizes the percentage decline in major crop yields across different regions over the last 10 years:

Region	Major Crop	Average Yield Decline (%)	Major Climatic Factor
Punjab	Wheat	8%	Rising temperatures
Madhya Pradesh	Soybean	10%	Drought
Bihar	Rice	12%	Erratic monsoon patterns
Odisha	Rice	15%	Flooding and cyclones

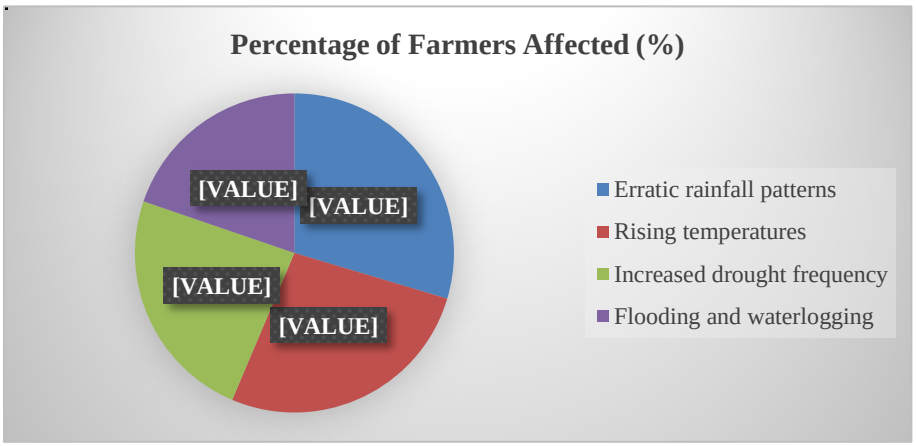


Rice agriculture in Bihar and Odisha has suffered 12% and 15% output decreases, respectively. Punjab and Madhya Pradesh wheat and soybean yields are also declining due to drought and temperature increases.

2. Farmer Perception of Climate Change

Over 85% of 200 farmers surveyed reported considerable climate change over the past decade. Most farmers cited unfavorable impacts from delayed or irregular monsoons, temperature variations, and more intense weather occurrences (Patel, S., Mall, R. K., Chaturvedi, A., Singh, R., & Chand, R. 2023). Table 2 breaks down farmer views on climate issues:

Climate Challenge	Percentage of Farmers Affected (%)
Erratic rainfall patterns	72%
Rising temperatures	65%
Increased drought frequency	58%
Flooding and waterlogging	48%



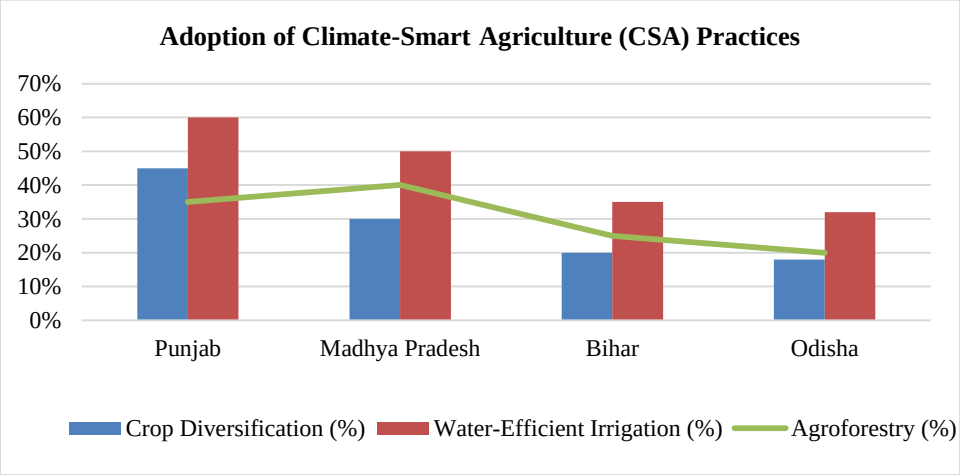
These data show that farmers most often mention irregular rainfall and rising temperatures, emphasizing the necessity for adaptable techniques to preserve food security.

3. Adoption of Climate-Smart Agriculture (CSA) Practices

The implementation of CSA techniques, including agroforestry, water-efficient irrigation systems, and crop diversification, was also examined in the study. The findings showed that although CSA procedures have been shown to be successful, they are still not widely used, especially in areas with low resources like Bihar and Odisha (Wakweya, R. B. 2023).

Table 3 illustrates the percentage of farmers who have adopted specific CSA practices across different regions:

Region	Crop Diversification (%)	Water-Efficient Irrigation (%)	Agroforestry (%)
Punjab	45%	60%	35%
Madhya Pradesh	30%	50%	40%
Bihar	20%	35%	25%
Odisha	18%	32%	20%



Bihar and Odisha trail behind, with less than 35% adoption in most categories, whereas Punjab has the greatest adoption rates of CSA techniques, with 60% of farmers utilizing water-efficient irrigation technologies. These areas' lower adoption rates can be ascribed to a lack of government assistance, low knowledge, and budgetary limitations.

4. Effectiveness of CSA in Improving Food Security

According to the study, increased food security and the implementation of CSA practices are positively correlated. Farmers in areas like Punjab, where CSA methods were more extensively implemented, reported more constant crop yields in spite of unfavorable weather conditions and more resilience to climate change. In particular, farmers that adopted water-efficient methods and crop diversification reported increased production and better resource management, which helped offset the adverse effects of climate unpredictability (Tilahun, G 2023)..

Farmers in areas like Bihar and Odisha, where CSA adoption is lower, nonetheless struggle greatly to maintain food production, and many of them report being more vulnerable to climate shocks. This demonstrates the pressing need for focused measures to encourage the adoption of CSA in these regions.

Discussion

The results of this study highlight the serious risk that climate change poses to India's food security, especially in areas where agriculture is a major industry. Crop output declines in Madhya Pradesh, Odisha, Punjab, and Bihar demonstrate how susceptible traditional farming methods are to climatic fluctuations. Extreme weather events, unpredictable rainfall, and rising temperatures are the main causes of these production declines.

One promising strategy to lessen these effects is to implement Climate-Smart Agriculture (CSA) techniques. Greater resilience to climatic shocks is seen in areas like Punjab, where CSA techniques like agricultural diversification and water-efficient irrigation are more common. However, limited CSA adoption in resource-poor areas like Bihar and Odisha suggests a lack of institutional support, funding, and awareness.

According to this research, increasing farmer education, expanding access to technology, and offering targeted financial help are essential for scaling CSA adoption and improving food security. To make sure that India's agriculture can adjust to the increasing problems presented by climate change, it will be crucial to fortify government regulations and incorporate CSA into larger agricultural frameworks.

Conclusion

With notable drops in crop yields in climate-sensitive areas, this study emphasizes the deep effects of climate change on India's agricultural sector and food security. This loss is mostly caused by rising temperatures, unpredictable rainfall, and a high frequency of extreme weather events, particularly in areas that are vulnerable like Bihar and Odisha. Even while Climate-Smart Agriculture (CSA) techniques like crop diversification, agroforestry, and water-efficient irrigation have been shown to be successful in reducing these effects, their uptake is still restricted, especially in regions with limited resources.

Scaling up CSA programs through focused government policy, more funding, and more farmer education is crucial to overcoming these obstacles. By extending the use of CSA techniques, India's agricultural sector may become far more climate change resilient, guaranteeing long-term food security. To make India's agriculture more sustainable and climate-resilient, future initiatives must concentrate on establishing conditions that allow farmers to implement CSA on a wider scale.

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Conflicts of interest
There are no conflicts of interest.

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