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The economic impact of climate change on global agricultural systems: A socio-economic perspective

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Abstract

Climate change, via rising temperatures, shifting rainfall patterns, increased frequency of extreme weather, and altered water availability, poses a mounting threat to global agricultural production. This paper reviews empirical evidence and model projections to assess the socio-economic implications of climate change on agriculture worldwide, with special attention to impacts on crop yields, rural livelihoods, food security, and regional disparities. Global analyses suggest substantial declines in yields for major staple crops, even when accounting for adaptation; in many low- and middle-income countries, agricultural output and household incomes are projected to suffer. The paper also explores impacts in the Indian context, where agriculture remains a major employer and the backbone of rural economies: studies forecast significant yield reductions in cereals and pulses, threatening food security and income stability for millions. Economic costs extend beyond yield losses to include price volatility, reduced labour productivity, and loss of competitiveness in agricultural trade. The review concludes that without robust adaptation, mitigation, and structural policy support, climate change will deepen rural poverty, intensify inequality, and undermine global food security.

Keywords: Climate change, agricultural yields, food security, economic impacts, adaptation

1. Introduction

Agriculture is the backbone of the global food system and plays a vital role in the livelihoods of billions of people. It is a key sector for both food production and economic development, particularly in developing countries where a large portion of the population relies on agriculture for income. However, agriculture is inherently vulnerable to changes in climatic conditions. Over the last few decades, global warming has led to shifts in temperature, altered rainfall patterns, and increased the frequency and intensity of extreme weather events, such as droughts, floods, and heatwaves^[1, 2]. These changes are increasingly threatening agricultural productivity, food security, and the socio-economic stability of rural economies.

The consequences of climate change on agriculture are far-reaching. Increased temperatures can stress crops, reduce yield potential, and alter growing seasons. For instance, warmer temperatures can shorten the growing season for many crops, thereby decreasing yields, especially for heat-sensitive crops such as wheat, rice, and maize. Shifts in rainfall patterns lead to either excessive water or droughts, both of which can severely affect crop production and make farming more unpredictable^[2, 3]. The increased occurrence of extreme weather events further exacerbates this issue, as such events can wipe out entire harvests, erode topsoil, and destroy critical agricultural infrastructure. These climate-induced challenges not only threaten crop production but also endanger the livelihoods of millions of smallholder farmers who are already vulnerable due to limited resources, poor access to technology, and dependence on rain-fed agriculture. Additionally, the socio-economic impact extends to the food security of populations, particularly in regions where agriculture is the primary source of sustenance and income^[3, 4]. The ripple effect of reduced agricultural productivity includes higher food prices, reduced farmer revenue, and a subsequent increase in rural poverty. Understanding how climate stress translates into these yield declines and economic losses is crucial for policymakers, stakeholders, and the global community^[4, 5]. It is essential to recognise the socio-economic consequences of these changes, especially for rural populations. While the impacts of climate

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change are global, developing countries face disproportionate risks due to limited adaptive capacities and vulnerability [5, 6]. This review synthesises existing knowledge on how climate change is affecting agricultural systems worldwide, with particular emphasis on developing countries and India, where agriculture is both a significant source of employment and a major driver of the economy [6, 7].

The paper also explores potential adaptation strategies and policy responses, which are crucial for reducing the adverse impacts of climate change [7, 8]. This includes assessing how different regions, particularly the most vulnerable, can enhance their resilience through technological innovation, improved agricultural practices, and policy interventions [8, 9]. The goal is to provide a comprehensive understanding of the current state of knowledge on the economic impacts of climate change on agriculture and to highlight the urgent need for coordinated global efforts to address these challenges [9, 10].

2. Mechanisms by Which Climate Change Affects Agriculture

Climate change affects agriculture through multiple, often interacting, channels:

- **Temperature rise and heat stress:** Higher temperatures can reduce crop growth periods, impair pollination, increase plant stress, and reduce yields. Heat stress can also degrade grain quality [5, 11].
- **Altered precipitation patterns and water stress:** Changes in timing, intensity, and regularity of rainfall — plus changes in evaporation demand — can cause droughts or waterlogging, both harmful to crops. Depletion of water

resources and reduced groundwater recharge further limit irrigation potential [12, 13].

- **Extreme weather events:** Increased frequency of droughts, floods, storms — each can destroy crops, erode soils, or damage infrastructure [13, 14].
- **Pests, diseases, and soil ecology:** Climate change can shift pest or pathogen ranges, alter soil microbiomes, and weaken plants, increasing vulnerability [14, 15].
- **Indirect effects via water, land, and socio-economic systems:** For example, reduced glacier/snow-melt in mountainous regions may alter river flows and irrigation availability; changes in water supply may affect competing demands from agriculture, industry, and households [15, 16].

These mechanisms often operate together; their relative importance depends on geography, crop type, farming practices, and adaptive capacity [16, 17].

3. Global Evidence: Crop Yields, Productivity, and Economic Impacts

3.1 Empirical and modelling studies on yield impacts

Recent global studies confirm that rising temperatures and climate variability are reducing yields of major staple crops. A 2025 study found that, for each degree of global warming, yields of maize, wheat, rice, and soybeans decline by 7.4%, 6%, 3.2%, and 3.1%, respectively [17, 18].

A primary 2025 global analysis (published June 18) concluded that even when accounting for farmers' adaptation and economic development, rising temperatures will reduce worldwide production capacity for staple crops [3, 6].

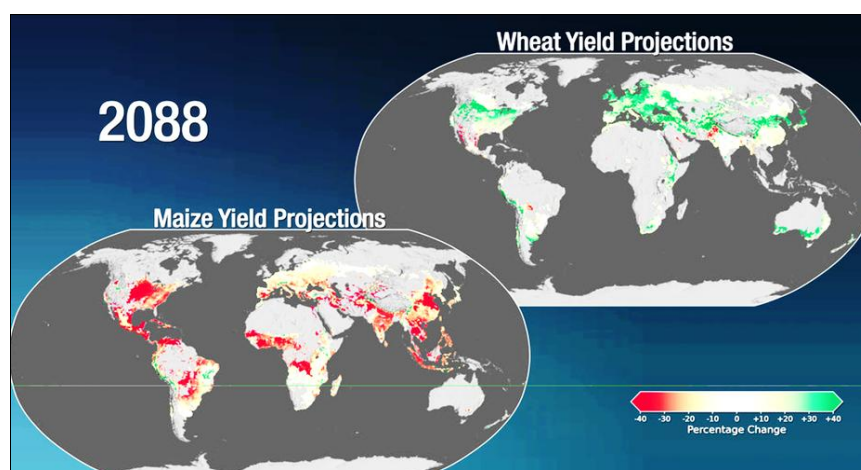


Fig: A map projecting spatial patterns of yield changes under future warming — useful to show regional variation (which regions lose most, which might gain). This links to studies projecting yield declines of up to ~41% in some areas under high emissions. (source: Hultgren, A., Carleton, T., Delgado, M. *et al.* Impacts of climate change on global agriculture accounting for adaptation. *Nature* 642, 644-652 (2025). <https://doi.org/10.1038/s41586-025-09085-w>)

3.2 Economic impacts beyond yields

Yield reductions translate into economic losses in multiple ways: lower output, income losses for producers, increased food prices, and greater volatility. (18,19) According to one review, climate change affects not only food quantity (yields) but also food quality, water availability, and increased pest and disease pressure — all of which reduce long-term agricultural sustainability [17, 18].

Some projections under high-emission scenarios suggest yield losses up to 41% in major producing regions, especially in tropical and subtropical zones [18, 19].

Overall, climate change undermines global food production

capacity, threatens the export competitiveness of producing countries, and increases the risk of supply disruptions [19, 20].

4. Socio-Economic Consequences: Food Security, Rural Livelihoods, and Price Volatility

4.1 Food Security Risks

Reduced yields, quality degradation, and increased supply volatility undermine food security, especially for low-income populations dependent on staples [20, 21]. Lower output raises food prices, facilitating access for vulnerable groups. In addition, the nutritional quality of crops may decline under stress, affecting micronutrient availability [21, 22].

4.2 Impact on Rural Livelihoods and Labour

In many countries, agriculture is a significant source of employment and income [22, 23]. Climate-induced yield losses reduce farm incomes, trigger farm-level financial stress, increase indebtedness, and force out-migration from rural areas. For farm labourers, reduced crop area and lower demand can reduce working opportunities [23, 24].

4.3 Price Volatility and Market Instability

Climate variability adds uncertainty to crop output, leading to volatile commodity prices [25, 26]. For consumers, this increases food insecurity; for producers, it results in unpredictable incomes. For countries dependent on agricultural exports — or imports — volatility can destabilise trade balances and foreign exchange revenues [26, 27].

4.4 Inequality and Regional Disparities

The impacts of climate change are uneven: regions with poor adaptive capacity (rainfed farming, smallholders, limited irrigation) suffer more. Wealthier, irrigated, or high-latitude regions may fare better [27, 28]. This deepens inequality between countries, regions, and even farmers within countries [11, 12]. Some mid- and high-latitude regions may see mild gains (primarily through CO₂ fertilisation), while low-latitude, tropical agriculture suffers [28, 29].

5. Case Study: Climate Change Impacts on Indian Agriculture

India provides an instructive example in which agriculture remains central to the economy and livelihoods, and vulnerability to climate change is high [29, 30].

5.1 Vulnerability of Indian Agriculture

A large fraction of Indian agriculture is rain-fed; changes in

monsoon patterns, rainfall variability, and groundwater stress pose serious threats [31, 30]. Historical data (1969-2005) show that changes in temperature, rainfall, and evapotranspiration have significantly affected yields of crops such as bajra, chickpea, groundnut, rice, and sugarcane [3, 7].

5.2 Projected Yield Losses

- Under climate change, projections estimate that for some crops, yield declines may reach 15-22% by 2100 [32, 33].
- For major cereal crops, some studies project sharp declines: under a 2.5-4.9°C temperature increase, wheat yields could drop by 41-52%; rice yield by 32-40% [33, 34].
- Recent reports (2025) warn of yield losses up to 25% across Indian agriculture due to erratic rainfall, drought, and rising temperatures [34, 35].

5.3 Economic & Socio-economic Impacts

Given that agriculture contributes around 15-18% of India’s GDP and employs a large share of the rural population, yield and output losses translate into significant economic damage [53, 54]. Reduced output may lead to rural income loss, migration, and reduced food security. As yields fall, the costs of staple foods may rise, affecting affordability [35, 36].

5.4 Evidence of Price & Yield Volatility

Studies show that extreme weather events — heat shocks and rainfall anomalies — significantly influence crop yield variability, especially in rice. This volatility undermines farmers’ predictable income and complicates planning for production, consumption, and trade [37, 38].

Table 1: Selected Projected Yield Losses in Indian Crops

Crop / Scenario	Projected Yield Loss*
Wheat (2.5-4.9 °C warming)	41-52% loss
Rice (same warming)	32-40% loss [38, 39]
Rice & Wheat (by 2100, moderate changes)	~15-22% loss
Mixed cereals/pulses (various)	Up to 25% yield loss projected for the agriculture sector overall [39, 40]

* Losses relative to baseline climate scenario without warming.

Table 2: Key Mechanisms of Impact in India

Mechanism	Impact on Agriculture & Economy
Altered rainfall & monsoon unpredictability	Rain-fed crops fail; irrigation demand rises; groundwater depletion.
Heat stress & higher temperatures	Reduced crop growth, lower yields, especially for wheat, rice, and pulses
Extreme weather events (drought, flood)	Crop failure, soil degradation, and economic vulnerability for farmers [40, 41]
Yield and price volatility	Income instability, market swings, food insecurity

6. Adaptation, Policy Responses, and Resilience Strategies

It is clear that without adaptation, agriculture faces a severe threat. Some strategies and policy responses are already under consideration or being implemented [41, 42].

- **Improved irrigation and water management:** Enhance water-use efficiency, invest in irrigation infrastructure, rainwater harvesting, and groundwater recharge. For regions dependent on monsoon or glacial meltwater (such as the Himalayas or northern India), protect and monitor water sources [42, 43].
- **Crop diversification and resilient crop varieties:** Develop and promote heat-, drought-, flood-, or salinity-tolerant crop varieties. Diversify cropping patterns to reduce reliance on

climate-sensitive staples [43, 44].

- **Agricultural planning & early warning systems:** Use climate forecasting, agro-climatic advisories, and scheduling planting/harvesting to avoid extreme events.
- **Institutional & policy support:** Provide safety nets, crop insurance, access to credit, support for smallholders, and invest in agricultural research. Governments should integrate climate risk into farm policy and incentives for sustainable practices [44, 45].
- **Technological & infrastructural investments:** Soil conservation, efficient irrigation (drip, sprinkler), improved storage, supply-chain resilience [45, 45].

However, a recent global analysis (2025) shows that even with realistic adaptation, yield losses remain significant. This highlights that adaptation helps, but is not a complete solution — mitigation of climate change must accompany adaptation ^[47, 48].

7. Challenges and Limitations in Estimation and Projections

Assessing the economic impacts of climate change on agriculture faces several challenges:

- **Complex interactions and non-linearity:** Effects depend on local climate, soil, crop, farming practices, water resources — responses are non-linear and heterogeneous.
- **Uncertainty in climate projections and emissions scenarios:** Projections vary based on warming scenarios (moderate vs high), assumptions about CO₂ fertilisation, technological change, and adaptation uptake ^[48, 49].
- **Adaptive behaviour & technological change:** Farmers may adopt new technologies, crop varieties, irrigation practices — these can mitigate some effects, but adoption rates vary widely. Hard to model realistically.
- **Data constraints:** In many developing countries, granular data on farm-level yields, climate exposure, socio-economic variables, and adaptation practices are limited ^[51, 52].
- **Economic spillovers and indirect effects:** Impacts go beyond yields — migration, labour markets, land-use changes, supply-chain disruptions, global commodity prices — these are harder to quantify.

Hence, estimates of economic impact, yield loss, and social consequences are subject to substantial uncertainty ^[48, 50].

8. Conclusion

Climate change poses a serious, wide-ranging threat to global agricultural systems. Evidence from both empirical studies and model projections establishes that rising temperatures, altered precipitation, and increased weather extremes will depress yields of major staple crops globally. These yield losses translate into substantial economic costs: lower farm incomes, higher food prices, increased price volatility, and heightened risk for food security.

In socio-economic terms, the consequences will likely be borne disproportionately by smallholder farmers, low-income populations, and regions with limited adaptive capacity. Countries like India — where agriculture remains central to livelihoods and GDP — face particularly steep challenges. Projections show significant yield declines in cereals and pulses, which could destabilise rural economies and the food supply.

Adaptation strategies such as improved irrigation, resilient crop varieties, diversification, climate-innovative agricultural practices, and supportive policies can mitigate some impacts. Yet recent global studies show adaptation alone cannot fully offset the damage. Without robust mitigation (i.e., reduction in greenhouse gas emissions), agriculture's long-term sustainability and global food security remain at risk.

Policymakers, researchers, and stakeholders must prioritise integrated approaches: combine mitigation and adaptation, invest in resilient agricultural infrastructure, support vulnerable farming communities, and build adaptive capacity globally. Failure to act risks undermining decades of development gains, exacerbating poverty and inequality, and threatening food security for billions.

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