Scientia Review, Vol. 01(03), September 2025, pp. 15-17

Scientia Review

Website: www.scientiafoundation.in

POPULAR SCIENCE ARTICLE

Climate Change Impacts in Agriculture

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Received: 24 August 2025
Revised: 28 August 2025
Accepted: 29 August 2025
Published online: 2 September 2025

Article ID: SR01019

Citation: Barman, B. & Nath, C. (2025). Climate Change Impacts in Agriculture. *Scientia Review*, 1(3), 15-17

Abstract

Climate change is one of the most pressing global challenges of the 21st century with agriculture standing at the frontline of its impacts. As the primary sector responsible for food production and rural livelihoods, agriculture is particularly vulnerable to shifts in temperature, precipitation patterns, extreme weather events and rising atmospheric carbon dioxide levels. The consequences of climate change in agriculture are multifaceted, encompassing reduced crop productivity, increased pest and disease outbreaks, loss of biodiversity, soil degradation and heightened risks to food security. Moreover, agriculture itself contributes significantly to greenhouse gas (GHG) emissions, making it both a victim and a driver of climate change. The major impacts of climate change on agriculture are reviewed here, supported by empirical studies and global reports, while also examining regional variations and adaptation strategies. A holistic approach that integrates climate-smart agriculture, sustainable land management, technological innovation and policy support is crucial to mitigate adverse effects and ensure long-term resilience.

Keywords: Climate, Agriculture, Food, Productivity, Adaptation, Mitigation, Pests, Resilience

Introduction

Climate change is no longer a distant threat; it is a present-day reality with significant consequences for natural ecosystems and human societies. Agriculture, as one of the most climate sensitive sectors, is experiencing profound transformations due to changing climatic conditions. According to the Intergovernmental Panel on Climate Change (IPCC, 2021) global average surface temperatures have already risen by approximately 1.1°C above pre-industrial levels, with projections suggesting a further increase by the end of the century depending on emission trajectories.

Agriculture is impacted through multiple channels including changes in growing season lengths, shifts in rainfall patterns, increased incidence of droughts and floods, soil erosion, pest proliferation and extreme heat stress (Lobell *et al*., 2011). At the same time, it is a significant contributor to greenhouse gas emissions, accounting for about 23% of total anthropogenic emissions when land-use change is included (IPCC, 2019). The sector therefore faces the dual challenge of reducing emissions while adapting to climatic stresses.

Climate Change Impacts on Agriculture

Impacts on Crop Production

Crop production is highly sensitive to climatic variables such as temperature, precipitation and atmospheric carbon dioxide concentration. Moderate warming may enhance crop growth in temperate regions but will likely reduce yields in tropical and subtropical regions (Porter *et al*., 2014). For instance, wheat and maize yields decline sharply with each degree rise in temperature beyond the optimal threshold (Lobell *et al*., 2011). Heat stress during critical growth stages such as pollination can drastically reduce grain set and productivity.

Rainfed agriculture, which supports nearly 80% of global cropland, is particularly vulnerable to erratic rainfall (Rockström *et al*., 2009). Drought reduces soil moisture and water availability while intense rainfall causes flooding and soil erosion. Elevated atmospheric CO_2 may enhance photosynthesis and biomass accumulation in C3

crops such as rice and wheat, but the benefits are limited by nutrient constraints and offset by negative impacts of heat and water stress (Ainsworth & Long, 2005). In India, studies project a 10–40% decline in crop yields by 2080 due to climate change (Aggarwal, 2008). In Sub-Saharan Africa, maize yields may decline by up to 20% by 2050 under high emission scenarios (Schlenker & Lobell, 2010).

Impacts on Livestock Production

Livestock systems are also vulnerable to climate change, particularly through heat stress, reduced feed quality and disease outbreaks. Higher temperatures reduce animal productivity, fertility and milk production. Dairy cows are especially sensitive to heat stress, with milk yield reductions observed in tropical regions (Nardone *et al*., 2010). Climate change also affects the availability and nutritional quality of forage crops, reducing protein content and digestibility. Warmer climates expand the range of vectors such as ticks and mosquitoes, increasing the incidence of livestock diseases like Rift Valley fever and bluetongue (Thornton *et al*., 2009).

Impacts on Fisheries and Aquaculture

Aquatic food systems are deeply influenced by rising temperatures, ocean acidification and changes in water availability. Shifts in sea surface temperatures cause changes in fish migration patterns and species distribution. Coral bleaching, caused by rising ocean temperatures, reduces fish habitats. Inland fisheries are threatened by changes in river flows and lake levels, particularly in South Asia and Africa. Higher temperatures in aquaculture systems increase the risk of fish diseases and reduce oxygen availability (FAO, 2018).

Soil and Water Resources

Soil health and water availability form the foundation of agriculture. Climate change accelerates soil erosion, nutrient depletion and salinization. Heavy rainfall events wash away fertile topsoil, reducing productivity. Rising demand for irrigation in response to increased evapotranspiration places stress on already scarce freshwater resources (Fischer *et al*., 2007). Groundwater depletion in major agricultural regions such as North India further exacerbates the crisis.

Pests, Diseases and Weeds

Climate change alters the distribution and intensity of agricultural pests, weeds and pathogens. Warmer temperatures accelerate pest life cycles, increasing their populations. For example, locust outbreaks in East Africa have been linked to unusual rainfall and warming events. Fungal and bacterial diseases thrive under warmer and wetter conditions, leading to yield losses. Climate change also favours the spread of invasive weed species that compete with crops for nutrients and water (Patterson, 1995).

Food Security and Socioeconomic Impacts

Climate-induced disruptions to agriculture threaten global food security in multiple ways. Declining yields reduce food supply, particularly in vulnerable regions. Reduced productivity drives up food prices and disproportionately affects poor households (Nelson *et al*., 2009). Increased frequency of extreme weather events disrupts food supply chains. Declines in crop nutrient content due to elevated CO_2 reduce dietary quality (Myers *et al*., 2014).

Adaptation and Mitigation Strategies

Climate-Smart Agriculture (CSA)

CSA integrates practices that increase productivity, enhance resilience and reduce emissions simultaneously (FAO, 2013). Examples include conservation agriculture such as reduced tillage, crop rotation and residue management. Integrated pest management (IPM) and water-saving technologies such as drip irrigation and rainwater harvesting also form essential components.

Technological Innovations

Advances in agricultural research and technology play a key role in combating climate challenges. Development of drought-resistant and stress-tolerant crop varieties through conventional breeding and biotechnology offers important solutions. Precision agriculture involving the use of remote sensing, GIS and IoT enhances efficiency in resource use. Digital agriculture supported by mobile applications and decision-support systems helps farmers make informed decisions using real-time climate information.

Policy and Institutional Measures

Governments and institutions can facilitate adaptation through risk transfer mechanisms like crop insurance and by strengthening agricultural extension services. Incentives for low-emission practices such as agroforestry and organic farming can further accelerate adoption.

Global Cooperation

International agreements such as the Paris Agreement emphasize reducing greenhouse gas emissions and supporting adaptation efforts in developing countries. Global collaboration is

vital to ensure resilience and equity in agricultural systems.

Conclusion

Climate change poses a profound challenge to global agriculture, threatening productivity, livelihoods and food security. The impacts are multidimensional, affecting crops, livestock, fisheries, soil and water resources. The vulnerability of agriculture underscores the urgency of adopting integrated adaptation and mitigation strategies. Climate-smart agriculture, technological innovation and supportive policy frameworks provide viable pathways to build resilience. Success will depend on coordinated global action, local-level adaptation and empowering farmers with knowledge and resources. Agriculture must transition towards sustainability not only to adapt to climate change but also to contribute meaningfully to its mitigation.

Conflict of interest

The authors declare no conflict of interest.

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