International Journal of Geography, Geology and Environment

P-ISSN: 2706-7483
E-ISSN: 2706-7491
IJGGE 2024; 6(1): 203-205
https://www.geojournal.net
Received: 05-11-2023
Accepted: 07-12-2023

Giuliano Pinna
Department of Agricultural, Food and Environmental Sciences, University of Perugia, Perugia, Italy

Mauro Dentali
Department of Agricultural, Food and Environmental Sciences, University of Perugia, Perugia, Italy

Corresponding Author:
Giuliano Pinna
Department of Agricultural, Food and Environmental Sciences, University of Perugia, Perugia, Italy

The impact of climate change on field crop productivity

Giuliano Pinna and Mauro Dentali

Abstract
This review paper explores the multifaceted impacts of climate change on field crop productivity, an issue of critical importance for global food security. With the ongoing shifts in temperature, precipitation patterns, carbon dioxide (CO_2) levels, and the frequency of extreme weather events, agricultural systems worldwide face unprecedented challenges. This paper synthesizes current scientific understanding of these impacts, drawing on a wide range of studies to highlight the complex interactions between climate variables and crop production. Moreover, it discusses adaptation and mitigation strategies essential for sustaining crop productivity in the face of these changes.

Keywords: Climate change, carbon dioxide (CO_2), global food security

Introduction
Climate change represents one of the most significant challenges to agricultural productivity in the 21st century. The increasing variability in weather patterns and climate extremes has profound implications for field crop production, which is inherently sensitive to environmental conditions. As the global population continues to grow, understanding and addressing the impact of climate change on agriculture becomes increasingly critical. This review aims to consolidate current knowledge on how changing climate conditions affect field crop productivity and to outline strategies to mitigate these impacts.

Objective of Review paper
The main objective of this review paper is to review the status of The Impact of Climate Change on Field Crop Productivity.

Literature Review
Negative Impacts Predominantly in Food-Insecure Regions: A systematic review and meta-analysis indicated that climate change could reduce the yield of major crops by about 8% by the 2050s in Africa and South Asia, with significant declines in the productivity of wheat, maize, sorghum, and millet due to warming temperatures and variable precipitation patterns (Knox *et al*., 2012) [1].

CO_2 Effects on Crop Yields: Increases in atmospheric carbon dioxide (CO_2) levels might offset some negative impacts of climate change by enhancing photosynthesis and water use efficiency, potentially leading to a net increase in global yields by about 1.8% per decade. However, warming trends are likely to decrease yields by roughly 1.5% per decade without effective adaptation strategies (Lobell & Gourdji, 2012) [2].

Regional Variability and Crop-Specific Responses: The impact of climate change on agricultural markets, taking into account 1.7 million fields around the world, suggests a modest global GDP reduction of 0.26%. This highlights the importance of trade and production adjustments in mitigating climate change impacts on agriculture (Costinot *et al*., 2014) [3].

Adaptation through Changing Sowing Dates: Research on maize in Peshawar showed that adjusting sowing dates could be an effective adaptation strategy, with early June sowing resulting in higher yields.

This suggests that climate change adaptation may include agronomic adjustments such as altering planting times (Ali *et al*., 2019) [4].

Climate Change and Field Crop Productivity
Temperature Changes
Temperature rises can lead to a reduction in crop yields by shortening the growing period and increasing heat stress, especially during critical phases of crop development such as flowering and grain filling. However, in some temperate regions, warmer temperatures may extend the growing season, potentially enhancing crop productivity.

Temperature Impact on Crop Growth Rate
The basic temperature response of crops can be modeled using a cardinal temperature formula, where growth rate is zero below a base temperature (T_base), increases linearly up to an optimum temperature (T_opt), and then declines beyond this point until it reaches a maximum temperature (T_max) at which growth stops.

$GR(T) = \{ 0$ if $T < T\_base$ or $T > T\_max$

$(T - T\_base) / (T\_opt - T\_base)$ if $T\_base \leq T < T\_opt$

$(T\_max - T) / (T\_max - T\_opt)$ if $T\_opt \leq T \leq T\_max \}$

Precipitation Variability
Alterations in rainfall patterns can result in droughts and floods, both of which are detrimental to field crops. Drought conditions limit water availability, crucial for crop growth, while excessive rainfall can lead to soil erosion and nutrient leaching.

Increased CO_2 Levels
Elevated CO_2 concentrations can stimulate photosynthesis in C3 crops, possibly leading to higher yields. Nonetheless, this potential benefit is often counteracted by the adverse effects of increased temperatures and precipitation variability.

CO_2 Fertilization Effect on Photosynthesis
Photosynthesis increase due to elevated CO_2 can be represented as a function of the current and pre-industrial CO_2 levels. A simple model might assume a logarithmic response of photosynthetic rate (A) to atmospheric CO_2 concentration (C):

$$A = A0 + b * \log(C / C0)$$

Where A0 is the photosynthetic rate at the pre-industrial CO_2 level (C0), C is the current CO_2 concentration, and b is a coefficient representing the sensitivity of photosynthesis to CO_2.

Extreme Weather Events
The increased incidence of extreme weather events, such as heatwaves, heavy rains, and droughts, can cause direct damage to crops, disrupt agricultural operations, and exacerbate pest and disease outbreaks.

Water Use Efficiency (WUE) under Climate Change
WUE is typically defined as the ratio of biomass produced (or yield) to the water used (evapotranspiration, ET). Climate change can affect WUE through changes in temperature, CO_2, and available moisture:

$$WUE = Yield / ET$$

Shifts in Pest and Disease Pressure
Climate change affects the distribution and lifecycle of pests and diseases, posing new challenges for crop management and potentially leading to increased crop losses.

Soil Health Impact
Soil health is crucial for crop productivity and is influenced by changes in climate. Temperature and precipitation shifts affect soil moisture, organic matter, and microbial activity, which in turn influence soil fertility.

Crop Yield Response to Climate Variables
A general empirical model to estimate crop yield response to climate variables might include terms for temperature, precipitation, and CO_2 concentration:

$$Yield = \alpha + \beta1*T + \beta2*P + \beta3*C + \varepsilon$$

Where T is average temperature, P is precipitation, C is CO_2 concentration, α is a constant, β1, β2, and β3 are coefficients for each variable, and ε represents error or other unaccounted factors.

Methodology
The data was collected from the various studies through the analysis method.

Results

Study	Year	Crops Studied	Major Findings	Impact (%)
Kumar *et al.*	2016	Major food and non-food grain crops	Climate change expected to decrease land productivity by 48.63% by 2100.	-48.63%
Rama Rao *et al.*	2022	Major food crops	Yields projected to decrease in majority of districts by mid-century and more significantly by end-century.	Varied by district
Mukherjee *et al.*	2021	Wheat	Increase in temperature and CO_2 might increase wheat yield by 3-28% across study sites.	+3% to +28%

This table provides a snapshot of the diverse impacts climate change can have on crop productivity in India, ranging from reductions in land productivity to potential increases in yield due to CO_2 fertilization and adaptation strategies. The percentages indicate projected changes in productivity or yield, highlighting the need for ongoing adaptation and mitigation strategies to safeguard agricultural output and food security in India.

Analysis
Diverse Impacts across Crops and Regions: The studies show a diverse range of impacts, from significant reductions in productivity to potential increases in yield. This variation is likely due to differences in regional climates, crop types, and the adaptive measures employed. For instance, Kumar

et al. (2016) [6] predict a significant decrease in land productivity by the end of the century, while Mukherjee *et al*. (2021) [8] indicate a potential increase in wheat yield due to elevated CO_2 levels and temperature changes.

Negative Effects Mitigated by Adaptation: The study by Kumar *et al*. (2016) [6] provides an interesting contrast to the others by highlighting that despite projections of yield decline due to climate change, actual yields have been increasing. This suggests that adaptation measures—such as the release and adoption of new crop varieties, increased irrigation, and the use of chemicals and fertilizers—are playing a crucial role in mitigating the negative impacts of climate change on agricultural productivity.

Projected Yield Declines: Rama Rao *et al*. (2022) [7] project yield declines in the majority of districts by mid-century, with deeper impacts anticipated by the end-century. This underscores the urgent need for targeted adaptation strategies to address the expected challenges in specific regions, especially considering India's vast agricultural diversity.

Variability and Uncertainty: The variance in impact percentages and outcomes across studies reflects the inherent uncertainties in projecting climate change impacts on agriculture. Factors such as future GHG emission scenarios, technological advances, policy changes, and the implementation of effective adaptation and mitigation strategies contribute to this uncertainty.

Importance of Irrigation and Fertilizers: Kumar *et al*. (2016) [6] emphasize the positive association of land productivity with irrigation and fertilizer application, suggesting that enhancing irrigation facilities and the recommended use of fertilizers could be crucial in combating the adverse effects of climate change.

Implications for Policy and Research: The findings indicate a pressing need for India to focus on climate-resilient agriculture through research, policy, and practice. Developing and disseminating climate-resilient crop varieties, enhancing irrigation infrastructure, and adopting sustainable farming practices are essential to ensuring food security and the livelihoods of millions.

Conclusion

The analysis of the impact of climate change on crop productivity in India reveals a complex scenario with both challenges and opportunities. While climate change is projected to decrease crop yields and land productivity in many regions, adaptation measures, including the adoption of climate-resilient crop varieties, enhanced irrigation, and appropriate use of fertilizers, have shown potential to mitigate these negative impacts. The varying projections highlight the importance of region-specific strategies and the critical role of ongoing research, policy support, and technological advancements in ensuring food security in the face of climate change. Ultimately, a concerted effort towards sustainable agriculture and climate resilience can help safeguard India's agricultural productivity and livelihoods of millions dependent on farming.

Reference

1. Knox J, Hess T, Daccache A, Wheeler T. Climate change impacts on crop productivity in Africa and South Asia. Environmental Research Letters; c2012, 7. https://doi.org/10.1088/1748-9326/7/3/034032.
2. Lobell D, Gourdji S. The Influence of Climate Change on Global Crop Productivity1. Plant Physiology. 2012;160:1686-1697. https://doi.org/10.1104/pp.112.208298.
3. Costinot A, Donaldson D, Smith C. Evolving Comparative Advantage and the Impact of Climate Change in Agricultural Markets: Evidence from 1.7 Million Fields around the World. Journal of Political Economy. 2014;124:205-248. https://doi.org/10.1086/684719.
4. Ali W, Khan M, Ali M. Sowing dates impact on maize varieties under climate change scenario. Ukrainian Journal of Ecology. 2019;9:97-101.
5. Kebede ZY. An overview of field crops production: The case of Metekel Zone: A review. Int. J Agric. Food Sci. 2021;3(2):42-46. DOI: 10.33545/2664844X.2021.v3.i2a.56
6. Kumar A, Sharma P, Joshi S. Assessing the Impacts of Climate Change on Land Productivity in Indian Crop Agriculture: An Evidence from Panel Data Analysis. Journal of Agricultural Science and Technology. 2016;18:1-13.
7. Rao C, Raju B, Samuel J, Rao A, Kumar R, Rao M, *et al*. Impact of climate change on productivity of food crops: a sub-national level assessment for India. Environmental Research Communications; c2022, 4. https://doi.org/10.1088/2515-7620/ac8b68.
8. Mukherjee A, Huda A, Saha S. Impact of climate change on future productivity and water use efficiency of wheat in eastern India. Theoretical and Applied Climatology. 2021;152:421-434. https://doi.org/10.1007/s00704-023-04409-0.