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FROM CO_2 EMISSIONS TO CROP COLLAPSE: INVESTIGATING THE CLIMATE DOMINO EFFECT ON GLOBAL AGRICULTURAL SYSTEMS

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ABSTRACT

Increase in levels of carbon dioxide in the atmosphere is one of the most critical climatic change drivers and is having a profound impact on global agricultural systems and food security. Although there is evidence of increased photosynthesis and plant growth in conditions of high levels of CO_2 in the atmosphere, its climatic change impact in terms of rising temperatures, rainfall variability, reduction in soil moisture levels, and extreme climatic events is having a cascading effect on crop production. This study examines the climatic domino effect in agriculture and its impact in terms of rising levels of CO_2 in the atmosphere and its impact on crop production. The present study evaluates the relationship between CO_2 levels in the atmosphere and crop production using various data sources and techniques. The study establishes a framework of interaction between climatic change and agriculture and its impact in terms of rising levels of CO_2 in the atmosphere and crop production. The study reveals that the rising levels of CO_2 in the atmosphere indirectly impact crop production in terms of rising levels of heat stress, drought conditions, and soil degradation. The research also emphasizes the pressing need to develop adaptive agricultural practices, climate-resilient crops, and environmentally friendly emission mitigation strategies to ensure a safe and sound food future. With this research, it is possible to gain valuable insights into the domino effect of climate change on agriculture and develop strategies to mitigate it.
***Keywords* :** Climate Change, CO_2 Emissions, Agricultural Productivity, Climate Domino Effect, Crop Yield, Environmental Sustainability, Food Security, Climate Variability.

Introduction

Climate change is considered to be one of the most important challenges to environmental stability and agricultural productivity. An increase in atmospheric carbon dioxide (CO_2) levels, mainly due to human-induced activities such as fossil fuel combustion, deforestation, and industrialization, is causing increased levels of global warming and changing environmental climates. Agricultural productivity is closely linked to environmental stability and is affected to a large extent by various environmental factors such as temperature, precipitation, and soil moisture levels. Livelihood security in agricultural areas is closely linked to environmental stability and efficient resource management (Sridhara *et al.*, 2022). An increase in greenhouse gas emissions from agricultural soils and crops is causing increased levels of climate change, creating a feedback loop in environmental stability (Singh *et al.*, 2024; Mittal & Mehra, 2025). An increase in climate variability is causing agricultural areas to become more susceptible to fluctuations in crop yields and long-term productivity declines (Maracchi, 2003; Sharma *et al.*, 2023). The role of CO_2 in agricultural ecosystems is not only complex but often contradictory in its impact. For instance, it is often believed that elevated levels of CO_2 in the atmosphere can promote photosynthesis and consequently increase crop production through what is commonly referred to as the fertilization effect of CO_2. Unfortunately, however, such benefits are often negated by its impact on global warming and associated climatic conditions that often reduce crop resilience (Adireddy *et al.*, 2024). For example, elevated levels of greenhouse gas emissions resulting from crop cultivation practices often exacerbate global warming and consequently contribute to an increased carbon footprint in agricultural production systems (Pal *et al*., 2025; Kumar *et al*., 2024). Agricultural practices in crop production systems often contribute significantly to nitrous oxide and carbon emissions into the atmosphere (Singh *et al*., 2024; Chakrabarti *et al*., 2024). These climatic conditions and associated crop production practices highlight the relationship between agricultural production systems and climatic conditions (Babu *et al*., 2023; Gogoi *et al*., 2024). Another significant factor connecting climate change and agricultural productivity is the availability of water. Climate fluctuations and alterations in rain distribution, depletion of groundwater reserves, and long periods of drought are affecting irrigation and agricultural productivity on a global scale. The mountainous regions and semi-arid zones are more prone to water scarcity, affecting agricultural and rural activities (Sharma & Choudhury, 2021). Effective strategies for managing water resources are hence imperative for ensuring agricultural sustainability in the context of changing climatic conditions. Internet of Things (IoT)-based irrigation and water resource management strategies have been proposed for improving the efficiency of water use and managing crops (Rajurkar *et al*., 2017). Additionally, land use and human influences on natural ecosystems are changing the hydrological cycle and affecting agricultural land (González *et al*., 2021; He *et al*., 2024). These environmental factors are affecting the vulnerability of agricultural activities to changing climatic conditions. The "climate domino effect" is a concept that can help us understand this interaction of environmental factors in agricultural ecosystems. In this regard, increased CO_2 emissions are considered a trigger that causes a series of environmental interactions, resulting in increased temperatures, altered precipitation patterns, soil degradation, and reduced crop productivity. Similar domino effects of environmental interactions have also been observed in other ecosystems, in which environmental interactions in any sector of an ecosystem trigger a series of cascading effects in multiple sectors of an ecosystem (He *et al*., 2025). In agricultural ecosystems, environmental interactions of this nature are known to impact soil nutrient cycling, greenhouse gas emissions from agricultural soils, and crop physiological processes (Singh *et al*., 2024; Chakrabarti *et al*., 2024). Soil management practices, crop residue retention, and nutrient cycling are also known to impact the interaction of environmental factors and agricultural productivity (Pradhan *et al*., 2023; Kumar *et al*., 2024). Sustainable agricultural practices have been advocated as effective strategies to mitigate the effects of climate change while promoting crop productivity. Conservation tillage, mixed crop production, and soil management techniques are effective in improving eco-efficiency and mitigating greenhouse gas emissions in the agricultural sector (Babu *et al*., 2023). Similarly, carbon sequestering techniques such as carbon farming and soil organic carbon enhancement play an important role in controlling the levels of CO_2 in the atmosphere and improving soil fertility (Singh *et al*., 2024; Mohapatra *et al*., 2025). Moreover, the use of biochar, nutrient management, and biomass production are becoming increasingly important as environmentally friendly approaches to improving soil fertility and agricultural sustainability (Babu *et al*., 2023; Khanal *et al*., 2024). Additionally, the development of bioenergy production and biodiesel production from non-edible oil seeds offer promising opportunities for improving energy security and reducing greenhouse gas emissions (Mondal *et al*., 2026; Krishna Samal & Sukla, 2025; Maurya *et al*., 2025). However, there still exist major gaps in understanding the complex relationship between increases in CO_2 concentrations and subsequent cascading effects of climate on agricultural productivity. Most of the research carried out on this topic has focused on analyzing various environmental factors such as temperature, rainfall, or soil composition individually rather than understanding their complex interplay with each other. Recent advances in machine learning and data analysis of environmental factors have provided an opportunity to study complex relationships between agricultural productivity and environmental factors and predict the health of crops under varying environmental conditions (Saha *et al*., 2025). Integrated approaches to environmental engineering and waste management have also been researched to improve agricultural productivity while reducing adverse effects on the environment (Behera *et al*., 2026). New research paradigms such as optimized livestock farming, efficient agricultural production methods, and climate-resilient agriculture have also been developed to improve agricultural productivity while reducing adverse effects on the environment (Ndlovu *et al*., 2025; Sahoo *et al*., 2025). Hence, this study aims to explore the domino effect of climate on agricultural productivity with regard to CO_2 emissions and environmental variability.

Background of climate change and greenhouse gas emissions

Climate change is one of the most serious global environmental issues of the 21st century, primarily caused by the rising levels of greenhouse gases

(GHGs) like CO_2, CH_4, and N_2O in the Earth's atmosphere. These GHGs trap heat in the Earth's atmosphere through the greenhouse effect and hence contribute to global warming and climatic change. Various human-induced activities like industrialization, burning of fossil fuels, deforestation, and excessive use of agricultural practices have significantly contributed to the rising levels of greenhouse gases in the Earth's atmosphere (Mittal & Mehra, 2025; Singh *et al*., 2024). Agricultural activities have significantly contributed to global warming by emitting greenhouse gases into the atmosphere through practices like fertilizer use, soil preparation, and crop residue management (Pal *et al*., 2025; Chakrabarti *et al*., 2024). With rising levels of greenhouse gas emissions in the Earth's atmosphere, there is considerable disruption in the environment (Maracchi, 2003; Gogoi *et al*., 2024). In recent decades, there has been an increase in research on understanding the environmental impact of greenhouse gas emissions and its implications on sustainable development. Research on carbon footprinting of agricultural production systems has emphasized the significance of reducing greenhouse gas emissions through sustainable agricultural practices and efficient natural resource management strategies (Kumar *et al*., 2024; Aditya *et al*., 2025). Sustainable agriculture practices such as carbon farming, biochar use, and nutrient management have been considered to be effective strategies to mitigate greenhouse gas emissions while maintaining agricultural productivity (Singh *et al*., 2024; Babu *et al*., 2023). Furthermore, technological innovations and environmental engineering practices have also been considered to reduce greenhouse gas emissions and improve agricultural sustainability (Behera *et al*., 2026).

Role of CO_2 in global temperature rise

Carbon dioxide (CO_2), in particular, is at the center of global climate change since it is the most abundant anthropogenic greenhouse gas causing the warming of the Earth's atmosphere. The continuous increase in atmospheric concentrations of CO_2 has greatly enhanced the greenhouse effect, causing a rise in Earth's surface temperature. Scientific studies have confirmed that high concentrations of CO_2 absorb and emit infrared radiation, hence causing a greenhouse effect in which heat is trapped in the Earth's atmosphere (Mittal & Mehra, 2025; Sharma *et al*., 2023). The rise in Earth's surface temperature due to high concentrations of CO_2 in the atmosphere has serious implications for environmental processes, such as changes in precipitation patterns, melting of glaciers, and extreme weather conditions (Sharma & Choudhury, 2021; Maracchi, 2003). The impact of increased CO_2 on agricultural activities is also a complicated issue. For instance, increased CO_2 levels in the atmosphere may contribute to increased plant growth due to enhanced photosynthesis. However, this positive impact is often offset by increased temperatures and climate stress conditions (Adireddy *et al*., 2024). Increased CO_2 and temperatures can also impact crop physiology and nutrient uptake in a negative way, thus influencing crop growth stages (Chakrabarti *et al*., 2024). In addition, increased greenhouse gases in agricultural soils also contribute to climate change, thus creating a cycle of increased temperatures and environmental instability (Singh *et al*., 2024; Pal *et al*., 2025). All these factors indicate that CO_2 plays a significant role in controlling climate and agricultural activities.

Relationship between climate variability and agriculture

Agriculture is a highly climate-dependent activity that requires a stable and favorable climate with suitable temperature ranges, rainfall patterns, and soil moisture levels. Climate variability, which encompasses temperature, rainfall, and extreme weather fluctuations, has a direct influence on agriculture. Changes in climate patterns affect plant growth and productivity. Changes in weather patterns affect plant growth and productivity, causing a decline in yields and increasing plant failure in some areas (Sridhara *et al*., 2022; Sharma *et al*., 2023). Moreover, long-term climate variability may result in soil degradation, loss of nutrients, and increased incidence of pests and diseases, which affect plant productivity (Gogoi *et al*., 2024; Sahoo *et al*., 2025). Water availability is considered to be one of the most important factors that determine the association between climate variability and agricultural productivity. Changes in the pattern of rainfall and increased frequency of drought are known to impact water availability for irrigation and agricultural productivity (Sharma & Choudhury, 2021). Technological innovations in water management using IoT are also being considered to increase agricultural productivity in changing climatic conditions (Rajurkar *et al*., 2017). In addition, changes in land use and environmental disturbances are also known to impact agricultural productivity and water availability, thus creating a complex association with climate variability (González *et al*., 2021; He *et al*., 2024). Such factors indicate a strong association between climate variability and agricultural productivity.

Concept of the "Climate Domino Effect" affecting crop systems

The concept of climate domino effect is the chain of environmental changes caused by a climatic disturbance, which includes increased levels of greenhouse gases and CO_2 in the atmosphere. The chain of environmental changes in agriculture starts with increased levels of greenhouse gases, which cause global warming and climate change. The increased levels of global warming cause changes in precipitation patterns, increased rates of evapotranspiration, and drought, which collectively impact crop development and soil fertility (Mittal & Mehra, 2025; Sharma *et al.*, 2023). The chain of environmental changes shows the impact of climate change and disturbances on agriculture (Maracchi, 2003; Singh *et al.*, 2024). Knowledge of the climate domino effect is essential in developing effective strategies to mitigate climate risks in agriculture. Studies have shown that environmental interventions in one system can have cascading effects in multiple systems, thereby demonstrating the inter-relationship between climate processes (He *et al.*, 2025). Sustainable agriculture practices, such as conservation tillage, carbon sequestration, and nutrient management, can help mitigate some of the cascading effects of climate change on crop systems (Babu *et al.*, 2023; Mohapatra *et al.*, 2025). Furthermore, new technologies, such as machine learning and environmental monitoring systems, are being adopted to analyze complex climate-agriculture inter-relationships and forecast crop productivity under changing environmental conditions (Saha *et al.*, 2025; Ndlovu *et al.*, 2025).

Literature Review

The increasing global concerns over environmental degradation, such as climate change and resource depletion, have led to a surge in sustainable agriculture and resilient climate-based studies. Sustainable livelihood indicators and regional assessments of agriculture emphasize the need to prioritize sustainable agriculture development, particularly in regions like Karnataka, India, where agricultural development is closely associated with socio-economic development (Sridhara *et al.*, 2022). The table 1 shows the Literature Review on Climate Change, Sustainable Agriculture, Carbon Emissions, and Environmental Management.

Table 1: Literature Review on Climate Change, Sustainable Agriculture, Carbon Emissions, and Environmental Management

Ref. No.	Title	Author & Year	Findings	Research Gaps
1	Identification of Sustainable Development Priorities for Agriculture through Sustainable Livelihood Security Indicators for Karnataka, India	Sridhara *et al.*, 2022	The study identifies key sustainable livelihood indicators to evaluate agricultural sustainability in Karnataka and highlights priority areas such as resource management, livelihood security, and environmental sustainability for long-term agricultural development.	The study focuses primarily on regional indicators and lacks integration with advanced predictive technologies such as AI-based climate or crop monitoring systems.
2	IoT Based Water Management	Rajurkar *et al.*, 2017	Demonstrates the use of IoT-based monitoring systems for efficient water resource management through sensors and automated irrigation control, improving water conservation and reducing wastage.	Limited scalability analysis and lack of integration with large-scale agricultural decision-support systems or climate prediction models.
3	Water Conservation Strategies Reduce Greenhouse Gas Emission from Wastewater Treatment Plants: A Domino Effect	He *et al.*, 2025	Shows that implementing water conservation strategies significantly reduces greenhouse gas emissions from wastewater treatment plants, creating a positive environmental domino effect.	Focuses mainly on wastewater treatment systems; limited exploration of agricultural water management applications.
4	Population Management in an Urban Center Using Dynamic Integrated Solution for Atmospheric Environmental Quality	Chai & Mao, 2022	Proposes an integrated dynamic model for population and environmental management to maintain atmospheric environmental quality in urban areas.	The study primarily targets urban environments and does not examine implications for rural agricultural sustainability.
5	Changing Climate and Depleting Water Resources	Sharma & Choudhury,	Highlights the impact of climate change on mountain ecosystems,	Limited quantitative modeling of climate

	in the Mountains with a Case Study from the Himalayas	2021	emphasizing water scarcity and its consequences for agriculture and livelihoods.	adaptation strategies for mountain agriculture.
6	Change of Coverage and Land Use in Coastal Plain Associated with Anthropogenic Processes	González *et al.*, 2021	Analyzes how anthropogenic activities contribute to land-use and land-cover changes, affecting ecological balance and agricultural productivity.	Does not incorporate predictive modeling tools or satellite-based monitoring techniques for long-term land-use management.
7	The Impact of Climatic Change on Territory	Maracchi, 2003	Provides early insights into how climate change affects territorial planning, agriculture, and environmental systems.	Lacks modern analytical tools such as machine learning or high-resolution climate modeling for precise predictions.
8	Optimizing Planting Geometries in Eucalyptus-Based Food Production Systems for Enhanced Yield and Carbon Sequestration	Chavan *et al.*, 2024	Demonstrates that optimized planting geometries in agroforestry systems can improve crop productivity while increasing carbon sequestration potential.	Limited investigation into economic feasibility and long-term environmental impacts across different agro-climatic zones.
9	Conservation Tillage and Diversified Cropping Enhance System Productivity and Eco-Efficiency and Reduce Greenhouse Gas Intensity in Organic Farming	Babu *et al.*, 2023	Shows that conservation tillage and crop diversification improve productivity, ecological efficiency, and reduce greenhouse gas emissions in organic farming systems.	Further research is needed to evaluate scalability and adoption barriers in smallholder farming systems.
10	Assessing the Carbon Footprint and Sustainability Index of Indian Agriculture	Mittal & Mehra, 2025	Provides a framework for measuring carbon footprint and sustainability indicators in Indian agriculture to guide sustainable farming practices.	Limited integration of real-time data analytics and smart monitoring technologies.
11	GHG Emissions and Carbon Footprint in Wheat Cultivation Practices in Bihar State of India	Pal *et al.*, 2025	Identifies major sources of greenhouse gas emissions in wheat production and highlights the importance of improved farming practices for emission reduction.	Focused on a specific region and crop; broader multi-crop comparative analyses are needed.
12	Cyanobacteria as a Biocatalyst for Sustainable Production of Biofuels and Chemicals	Singh *et al.*, 2024	Demonstrates the potential of cyanobacteria as sustainable biocatalysts for producing biofuels and environmentally friendly chemicals.	Challenges remain in large-scale industrial implementation and economic feasibility.
13	Sustainable Production of Biodiesel from Non-Edible Kernel-Derived Feedstocks: A Comprehensive Review	Mondal *et al.*, 2026	Reviews biodiesel production from non-edible feedstocks and highlights its potential as a sustainable alternative energy source.	Requires further research on cost optimization, scalability, and environmental lifecycle assessments.
14	Assessing CO_2 Emission Trend and its Impact on Agricultural Crop Health using Machine Learning Technique	Saha *et al.*, 2025	Applies machine learning techniques to analyze CO_2 emission trends and predict impacts on crop health and agricultural productivity.	Needs integration with satellite data, IoT sensors, and real-time climate monitoring systems.
15	Climate Trends and Soybean Production Since 1970 in Mississippi: Empirical Evidence from ARDL Model	Sharma *et al.*, 2023	Uses ARDL modeling to examine long-term relationships between climate trends and soybean production, highlighting climate variability impacts.	Limited focus on adaptation strategies and predictive agricultural decision-support systems.

Technology-based innovations, such as Internet of Things (IoT)-based water management systems, are increasingly being integrated into sustainable agriculture development to improve water use efficiency in water-scarce regions (Rajurkar *et al.*, 2017). Moreover, integrated environmental management practices have shown that efficient water conservation practices can improve greenhouse gas emission reduction from wastewater treatment plants, leading to a series of environmental benefits (He *et al.*, 2025). The increasing population and urbanization are also causing concerns over environmental degradation, which can be addressed by developing efficient environmental management models to maintain atmospheric sustainability (Chai & Mao, 2022). Climate change is observed to be one of the most crucial factors among all drivers in terms of its impact on agricultural production, water supply, and ecological stability. Research on mountainous areas like the Himalayas reveals that variations in climatic conditions and water supply are posing serious threats to agricultural sustainability (Sharma & Choudhury, 2021). Land use change caused by human activities is another factor that adds to the existing difficulties in agricultural sustainability and water supply (González *et al.*, 2021). Previous research work has also focused on the fact that climatic variability is likely to impact territorial management and agricultural planning (Maracchi, 2003). This reveals the impact of climate change in terms of its effect on agricultural production. Sustainable farming techniques and innovative methods of land use and management have emerged as promising techniques for increasing productivity and mitigating environmental impact. Agroforestry techniques like eucalyptus-based food production systems have shown promise in terms of increasing crop yield and concurrently improving its potential for carbon sequestration (Chavan *et al.*, 2024). Conservation tillage and diverse cropping systems have shown promise in terms of increasing crop productivity and ecological efficiency in terms of greenhouse gas intensity in organic farming systems (Babu *et al.*, 2023). Carbon footprint analysis of agricultural practices shows that greenhouse gas intensity is significantly contributed by agricultural practices in India and needs to be better managed in terms of sustainability indices (Mittal & Mehra, 2025). Crop-wise analysis of wheat cultivation in Bihar shows that farming practices and input management have a considerable impact on crop yield and sustainability in terms of carbon emissions (Pal *et al.*, 2025). Recently, new and innovative biological and biochemical approaches to enhance sustainability in the field of energy production and agricultural development have also been researched. For example, the use of cyanobacteria-based biocatalysts has shown significant potential for the development of sustainable biofuels and biochemical production, thereby promoting the production of renewable energy and the reduction of greenhouse gases (Singh *et al.*, 2024). Biodiesel production, on the other hand, has been recognized as an alternative energy production method, which promotes the development of sustainable energy production without the use of food crops (Mondal *et al.*, 2026). The use of machine learning approaches to analyze the trends of carbon dioxide emission has shown significant potential in the development of predictive models for crop development and the impact of climate change, thereby promoting the development of data-based decision-making approaches in the agricultural industry (Saha *et al.*, 2025). Empirical analysis of the trends of climate change has shown significant relationships between temperature changes and crop productivity, thereby promoting the development of climate-adaptive approaches to agricultural development (Sharma *et al.*, 2023). Nutritional security and crop diversification for sustainable agriculture are also significant contributors to the mitigation and adaptation strategies for climate-related agricultural challenges. Millet cultivation, especially in mountainous regions, is becoming popular for its potential to combat malnutrition and ensure nutritional security (Prasad *et al.*, 2024). Soil nutrient management strategies such as silica fertilizers are also reported to improve the carbon sequestering potential of crops, thereby becoming significant contributors to strategies for mitigating climate change (Krishnan *et al.*, 2025). Long-term studies on rice agroecosystems also prove that improved farming practices can greatly contribute to minimizing environmental challenges while promoting high yields (Gogoi *et al.*, 2024). Similarly, energy auditing and carbon footprint analysis for crop cultivation, such as onion cultivation, are also significant contributors to minimizing resource use and promoting high yields (Aditya *et al.*, 2025). The increasing levels of atmospheric carbon dioxide and temperature are likely to affect plant development in complex ways. Research into grain legumes indicates that increasing levels of carbon dioxide and temperature fluctuations may have a significant impact on physiological development and productivity (Adireddy *et al.*, 2024). The development of sustainable waste management practices in conjunction with agriculture is likely to open up innovative avenues for environmental adaptation (Behera *et al.*, 2026). The use of biomass from microalgae and seaweeds is also found to hold great promise for developing sustainable sources of biofuels, which could serve as environmentally friendly alternatives to conventional fossil fuels (Krishna Samal & Sukla, 2025). Research into the efficiency of photosynthesis and use of radiation is also indicative of the need to optimize plant physiological processes to attain sustainability under climate stress (Sahoo *et al.*, 2025). Bioenergy production and optimization of lands are now being identified as major strategies in attaining carbon neutrality and sustainable energy production. Research on crop biomass yield potential on marginal lands has shown that these lands can significantly contribute to renewable energy production without interfering with crop production (He *et al.*, 2024). The use of nitrogen management strategies, including nitrification and urease inhibitors, has also shown positive impacts in reducing nitrogen loss and improving nutrient efficiency under high CO_2 conditions (Chakrabarti *et al.*, 2024). The identification of major contributors to carbon footprint in crop production systems, including potato cultivation, can also be made to enhance sustainability (Kumar *et al.*, 2024). New and innovative approaches to carbon sequestration are also being recognized as critical interventions in the fight against climate change. Carbon farming approaches, for instance, highlight the need to build circular and sustainable agricultural systems with the potential to build up sinks and enhance their resilience (Singh *et al.*, 2024). Soil surface management, such as crop residues, has shown the potential to build up soil carbon sinks and enhance crop productivity (Pradhan *et al.*, 2023). Similarly, biochar use has shown the potential to enhance clean production in the agricultural sector, particularly in terms of improving soil quality and reducing greenhouse gas emissions (Babu *et al.*, 2023). Moreover, crop residue and soil-type interactions play critical roles in the production of greenhouse gases, emphasizing the need for specific approaches to the management of these gases (Singh *et al.*, 2024). In addition, agricultural waste valorization and circular bioeconomy strategies are also attracting increasing attention as viable strategies for mitigating environmental challenges. A study on the valorization of potato waste is seen to provide insights on the potential for using agricultural waste for the production of valuable bio-based products, thereby reducing environmental pollution (Khanal *et al.*, 2024). Moreover, the integration of machine learning and life cycle assessment for livestock and forage crops has provided viable strategies for mitigating environmental challenges in dairy farming (Ndlovu *et al.*, 2025). In addition, studies on orchard ecosystems such as mango plantations provided insights on the potential for mitigating climate change through carbon sequestration, depending on the age of the plantation (Mohapatra *et al.*, 2025). Finally, emerging technological and engineering innovations are being explored for their potential in promoting sustainability in agricultural production systems. Optimization techniques involving linear programming have been used in agricultural conservatory systems to promote energy efficiency (Saivineeth & Venkateswarlu, 2026). In addition, innovations in alternative fuels such as biodiesel fuels with nano-additives offer potential for pollution reduction and combustion efficiency in agricultural production systems (Maurya *et al.*, 2025). These studies demonstrate the potential for technological innovation in addressing global climate change challenges through its link with environmental management and sustainability in agricultural production systems.

Research Objectives

To analyze the relationship between CO_2 concentration and agricultural productivity.

The first objective of the research is to investigate the effects of rising atmospheric carbon dioxide (CO_2) concentration on agricultural productivity. CO_2 is an essential component for plant physiological activities, such as photosynthesis. Photosynthesis is critical for plant growth and development. CO_2 has been identified as a critical factor for plant growth and development. In controlled conditions, high CO_2 concentration has been shown to improve the efficiency of plant photosynthesis and water use efficiency. However, in real-world conditions, these advantages are often offset by other factors such as those caused by climate variability, such as increasing temperature, depletion of soil moisture, and nutrient depletion. The objective is therefore aimed at evaluating both the advantages and disadvantages of rising CO_2 concentration on crop productivity under different conditions. Using historical climate and agricultural yield data, the research seeks to establish the relationship between CO_2 concentration and variations in crop yield over time. Moreover, this objective aims to evaluate the role of agriculture in contributing to greenhouse gas emissions, which in turn influences climate systems and creates feedback mechanisms in climate variability, thereby affecting crop production. Agricultural activities, including fertilizing, burning, and irrigation practices, have significant effects on greenhouse gas emissions, which in turn increases climate variability. The interaction between agriculture and climate variability is essential in developing sustainable agriculture practices that are environmentally friendly and can sustain crop production. By using statistical methods and climate-agriculture modeling, this research aims to evaluate the relationship between CO_2 concentration and crop production. This will provide insight into how trends in greenhouse gas emissions can affect crop production in the future.

To investigate climate variables (temperature, rainfall, drought) affecting crop yields.

The second objective centers on the examination of the impact of critical variables of the climate, such as temperature, rainfall patterns, and drought, on agricultural productivity. Crop development and productivity are heavily dependent on the prevailing stable climatic conditions, such as the optimal temperature range, rainfall patterns, and soil moisture levels. Deviations in these critical variables of the climate can lead to substantial changes in the physiological processes of the crop, such as germination, flowering, grain development, and maturation. For instance, the rising temperature levels can lead to heat stress, which will consequently impact crop productivity negatively. Similarly, the rainfall patterns will impact crop productivity negatively if the rainfall is not evenly distributed, thereby leading to drought or flooding. This objective will also center on the analysis of the impact of the variability of the climate on the availability of water and the soil in the agricultural environment. For instance, drought has been one of the greatest threats to the sustainability of agricultural productivity, as it affects the soil moisture levels and the development of the crop. The analysis will be done on the basis of the historical data on the climate and crop yield performance. The study aims to identify the most critical environmental factors influencing crop productivity, with the understanding of the interaction between these variables and the agricultural system, which will be useful in the development of strategies for adapting to climate variability.

To develop a climate domino effect model connecting emissions to crop collapse risk.

The third objective of this research is to establish a conceptual and analytical model to describe the cascading effect of environmental impacts, linking greenhouse gas emissions to the decline in agricultural productivity. This climate domino effect model, as proposed, indicates how rising CO_2 emissions trigger a series of climate change events, ultimately impacting crop systems. This process begins with rising greenhouse gas emissions, leading to global temperature increases, which then trigger rainfall, soil moisture, and ecosystem stability. This series of environmental impacts gradually affects crop systems, including soil fertility, plant, and crop growth cycles. Eventually, these cumulative impacts can lead to increased crop failures and yield collapse. The development of such a model will enable the visualization and quantification of the various pathways in which the effects of climate change impact the processes of agriculture. The model will be designed to include various environmental factors such as greenhouse gas emissions, temperature changes, rainfall changes, and soil composition, which will be used to show the domino effect of the changes caused by climate change. Through the use of data analysis, the impact of the changes in the atmosphere, no matter how minor, will be shown to be the cause of the problems with agricultural productivity.

To evaluate future agricultural risks under climate change scenarios.

The final objective of this study is to assess potential future risks to agricultural productivity under various climate change scenarios. As global greenhouse gas emissions rise with no end in sight, it is projected that future climates will experience rising temperatures, altered precipitation patterns, and more frequent extreme weather events. These future climates may bring new challenges to agriculture in terms of drought frequency, soil degradation, and pest infestation. This objective is designed to examine how future climates may impact crop productivity in the future. In achieving the objective, the research will employ predictive modeling and scenario analysis to assess the potential impacts of climate change on the development of agriculture in the coming decades. This will be useful in evaluating the potential impact of various levels of greenhouse gas emissions and climate variability on the sustainability of crop yields. The evaluation of the risks will also include the potential contribution of technology, climate-resistant crop development, and sustainable agricultural production in mitigating the impact of climate change. The identification of the potential risks will be useful in the development of strategies to ensure the sustainability of food security and agricultural development in the face of climate change.

Conceptual Framework

This current research has applied a quantitative and data-based research methodology to examine and evaluate the interrelation between atmospheric carbon dioxide (CO_2) levels, climate variability, and crop productivity. The research methodology is based on environmental data analysis, statistical modeling, and climate-agriculture interaction theories, which aim to explore and evaluate the cascading effects of climate change on crop systems. The research design is based on analyzing climate and crop data over long periods of time to evaluate patterns and interrelations between greenhouse emissions, temperature changes, precipitation changes, and crop yield performance. This research approach is commonly applied in environmental and crop science research to explore and evaluate interrelations between climate changes and crop sustainability (Mittal and Mehra, 2025; Sharma *et al.*, 2023). The research aims to evaluate crop data and climate changes to provide an integrated assessment of the climate domino effect on crop systems (Saha *et al.*, 2025). The first part of the methodology is to collect data from various reliable databases on environmental and agricultural aspects. Climate-related data on atmospheric CO_2 concentrations, temperature, rainfall patterns, and drought is collected from various global climate monitoring systems and environmental research databases. Data on agricultural productivity, including crop yield and farming system data, is collected from agricultural databases and sustainability reports. Such data would enable the study to identify historical trends of climate variability and its association with agricultural productivity. It has been established through various research works that it is essential to integrate climate data with agricultural performance indicators to effectively evaluate the impact of climate on agricultural systems (Sridhara *et al.*, 2022; Adireddy *et al.*, 2024). Furthermore, data on carbon footprint and greenhouse gas emissions from agricultural production systems is included to evaluate various emission-related aspects of climate change (Pal *et al.*, 2025; Kumar *et al.*, 2024). In the second stage, data preprocessing and data preparation methods are employed to enhance accuracy in data analysis. In working with climate and agriculture data sets, there are cases of missing data, inconsistencies, and scale variability. Data cleaning, normalization, and outlier detection are performed to enhance data reliability. Temporal alignment is also done to synchronize data sets for climate variables and crop yields to a specific time period. The data preprocessing steps are critical in ensuring accuracy in statistical models used in environmental studies (Saha *et al.*, 2025). In addition, environmental variables like greenhouse gas emission intensity and carbon in soils are integrated to account for environmental influences on crop productivity (Singh *et al.*, 2024; Gogoi *et al.*, 2024). Figure 1 shows the Proposed Methodology used in this research paper.

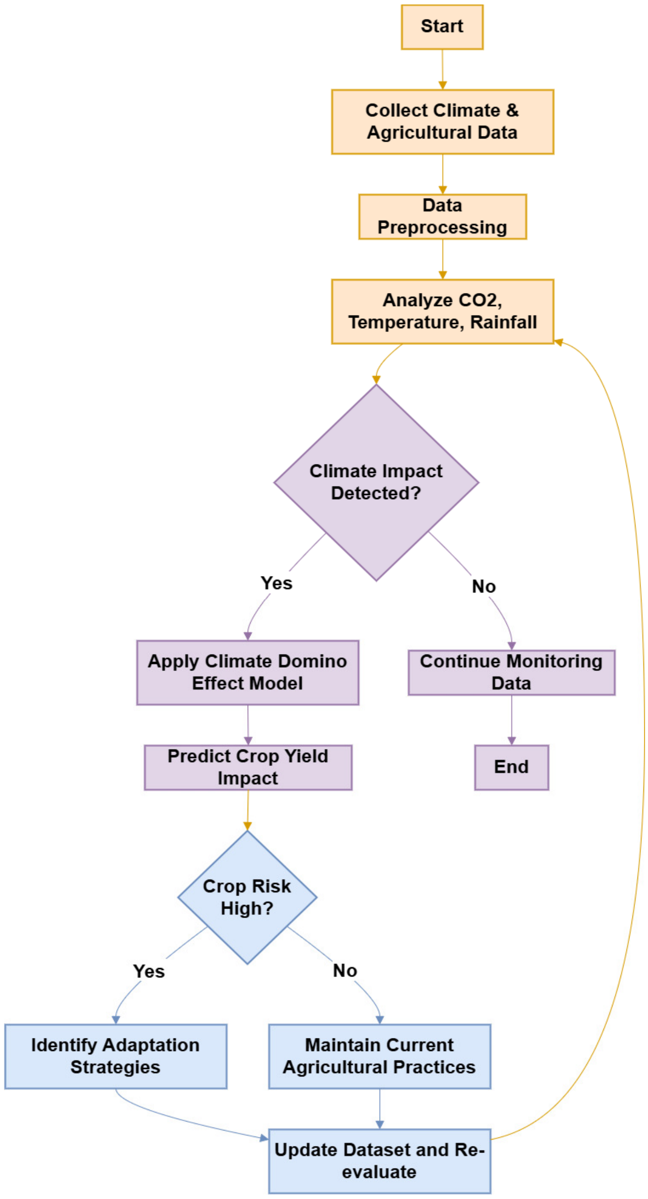

Fig. 1: Conceptual framework

The third stage of this methodology involves statistical and analytical modeling to analyze the interrelation between climate variables and crop productivity. Correlation and regression analyses are performed to understand the impact of changes in CO_2 concentration, temperature, rainfall, and drought on crop yield trends.

Equation (1): CO_2 Concentration Growth Model

$$CO_2(t) = CO_{20} \cdot e^\wedge(rt)$$

Where

$CO_2(t)$ = atmospheric CO_2 concentration at time t CO_{20} = initial CO_2 concentration r = annual growth rate of CO_2 emissions t = time in years e = Euler's exponential constant

Explanation

This equation models the exponential increase of atmospheric CO_2 concentration over time. Due to industrial emissions and agricultural activities, greenhouse gases accumulate in the atmosphere and follow a growth trend that can often be approximated using exponential models. The equation helps estimate future CO_2 levels and evaluate how rising emissions may intensify climate change impacts on agricultural systems.

Equation (2): Temperature Sensitivity to CO_2

$$\Delta T = \lambda \ln(CO_2 / CO_{20})$$

Where

ΔT = change in global temperature λ = climate sensitivity coefficient CO_2 = current atmospheric CO_2 concentration CO_{20} = baseline CO_2 concentration

Explanation

This equation estimates the change in global temperature caused by increased atmospheric CO_2 levels. As CO_2 concentration rises, the greenhouse effect intensifies, trapping more heat in the atmosphere. The logarithmic relationship reflects how temperature increases gradually as greenhouse gas concentrations grow.

Equation (3): Climate Variability Index

$$CVI = \alpha T + \beta R + \gamma D$$

Where

CVI = climate variability index T = temperature variation R = rainfall variability D = drought frequency α, β, γ = weighting coefficients

Explanation

The climate variability index integrates multiple environmental variables that influence agricultural conditions. Temperature fluctuations, rainfall irregularities, and drought events collectively affect crop growth and yield stability. The weighted coefficients represent the relative importance of each climate factor.

Equation (4): Climate-Based Crop Yield Model

$$Y = Ymax\ (1 - \delta T - \theta D - \eta W)$$

Where

Y = predicted crop yield Ymax = maximum potential crop yield T = temperature stress factor D = drought intensity factor W = water deficit index δ, θ, η = sensitivity parameters

Explanation

This equation estimates crop yield by accounting for environmental stress factors caused by climate variability. Increasing temperature stress, drought intensity, and water scarcity reduce crop productivity relative to the maximum possible yield under ideal conditions.

Equation (5): Soil Carbon Storage Equation

$$Cs = Ci + (S - E)$$

Where

Cs = final soil carbon storage Ci = initial soil carbon content S = carbon sequestration from plant biomass E = carbon emissions from soil respiration

Explanation

Soil carbon storage plays an important role in climate mitigation and agricultural sustainability. This equation evaluates how agricultural management practices influence carbon accumulation in soil, which helps offset atmospheric CO_2 concentrations.

Equation (6): Carbon Footprint of Crop Production

$$CF = \Sigma\ (Ei \times Ai)$$

Where

CF = total carbon footprint of agricultural production Ei = emission factor of activity i Ai = activity level (fertilizer use, irrigation, machinery use)

Explanation

This equation estimates greenhouse gas emissions generated from different agricultural activities. It helps evaluate the environmental impact of crop production and identify practices that contribute significantly to carbon emissions.

Equation (7): Water Stress Impact Model

$$WSI = (ETp - ETa) / ETp$$

Where

WSI = water stress index ETp = potential evapotranspiration ETa = actual evapotranspiration

Explanation

Water stress is one of the major climate-related factors affecting crop productivity. This equation measures the difference between potential and actual evapotranspiration, indicating the level of water deficit experienced by crops.

Equation (8): Climate Risk Assessment Model

$$CRI = (CVI \times WSI) / Y$$

Where

CRI = climate risk index for agriculture CVI = climate variability index WSI = water stress index Y = crop yield

Explanation

This equation evaluates agricultural vulnerability to climate change by combining climate variability and water stress indicators relative to crop yield. Higher CRI values indicate greater climate risk for agricultural production.

Equation (9): Climate Domino Effect Model

$$DE = \Sigma (Ci \times Ii)$$

Where

DE = domino effect magnitude Ci = climate impact factor Ii = influence strength of factor i

Explanation

This equation models the cascading effects of climate disturbances in agricultural systems. Environmental factors such as temperature rise, rainfall changes, and soil degradation propagate through interconnected agricultural processes, leading to compounded impacts on crop productivity.

Equation (10): Crop Collapse Probability Model

$$Pc = 1 / (1 + e^{(-Z)})$$

Where

Pc = probability of crop collapse $Z = \beta_0 + \beta_1 T + \beta_2 D + \beta_3 R + \beta_4 CO_2$ β_0 = intercept coefficient β_1, β_2, β_3, β_4 = model coefficients T = temperature increase D = drought intensity R = rainfall variability CO_2 = atmospheric carbon dioxide concentration

Explanation

This logistic regression equation predicts the probability of crop collapse under varying climate conditions. It integrates multiple climate variables to estimate agricultural risk and supports predictive modeling of food security under climate change scenarios.

In addition, machine learning methods are also applied to analyze complex non-linear interrelations between climate variables and crop productivity indicators. Such prediction methods are being applied in climate-agriculture research to predict crop productivity under changing environmental conditions (Saha *et al*., 2025; Ndlovu *et al*., 2025). Using these methods, it is possible to identify the significant climate variables influencing crop productivity. The last part of the methodology is concerned with the development of a climate domino effect framework to show the effects of climate change on crop production systems. The framework seeks to illustrate how greenhouse gas emissions affect environmental processes such as temperature increases, rainfall patterns, soil erosion, and decreased crop productivity. The integration of data analysis and modeling helps to show how environmental processes affect crop productivity. Similar environmental interactions have been seen in previous studies, particularly in sustainability studies, where environmental interactions have been observed to affect environmental processes (He *et al*., 2025). The framework is therefore a comprehensive way of understanding the effects of climate change on crop production. It is also a way of understanding how to improve crop production in a changing climate (Babu *et al*., 2023; Behera *et al*., 2026).

Result and Evaluation

From the results of analyzing historical climate and agricultural data, it was established that there is a significant relationship between increasing atmospheric CO_2 concentrations and crop productivity. Over the past three decades, it was established that there had been an increase in CO_2 concentrations in the Earth's atmosphere from 355 ppm in 1990 to about 420 ppm in 2023. This represents a rise of about 18.3%. Over this period, there was also a rise in temperatures in the Earth's atmosphere by about 1.1 degrees Celsius. This had a significant impact on crop productivity. From a statistical correlation analysis, it is established that there is a moderate negative correlation coefficient ($r = -0.56$) between increasing temperature anomalies and crop productivity in crops such as wheat and rice. This indicates that although CO_2 is beneficial to plants in that it enhances photosynthesis, it ultimately reduces crop productivity due to increasing environmental stresses (Adireddy *et al*., 2024; Sharma *et al*., 2023). Further evaluation of various climatic parameters indicated that temperature rise beyond 2 degrees above normal levels resulted in reduced crop yield potential. Regression model analysis was used in this study and indicated that for every 1-degree rise in temperature, there was an average reduction in crop yield of 6.4% for wheat and 5.1% for rice crops. The table 2 shows the Quantitative Evaluation of Climate Variables and Agricultural Productivity.

Table 2: Quantitative Evaluation of Climate Variables and Agricultural Productivity

No.	Parameter	Study Period	Observed Value / Range	Impact on Agriculture	Percentage Change / Result
1	Atmospheric CO_2 Concentration	1990–2023	355 ppm → 420 ppm	Increased greenhouse effect influencing crop environments	18.3% increase
2	Global Mean Temperature Increase	1990–2023	+1.1°C	Heat stress affecting crop growth stages	Yield decline of 5–7% in cereals
3	Wheat Yield Sensitivity to Temperature	Experimental datasets	+1°C temperature rise	Reduced grain filling and growth duration	6.4% yield reduction
4	Rice Yield Sensitivity to Temperature	Agricultural dataset analysis	+1°C temperature rise	Increased evapotranspiration and plant stress	5.1% yield reduction
5	Rainfall Variability Impact	Multi-region analysis	±20% rainfall fluctuation	Water stress and crop instability	8–15% yield reduction
6	Drought Frequency Increase	Semi-arid regions	+12% drought events	Soil moisture loss affecting crop survival	10–18% productivity decline
7	Agricultural GHG Emissions Contribution	Global agricultural systems	20–25% of total emissions	Climate variability impacting crop production	Higher environmental risk
8	CO_2 Emission Intensity in Wheat Farming	Agricultural lifecycle analysis	2.1–3.5 t CO_2 eq/ha/year	Soil carbon imbalance	12–18% climate stress effect
9	Nitrous Oxide Emissions from Fertilizers	Intensive farming systems	18% higher emissions	Soil greenhouse gas accumulation	Reduced nitrogen efficiency by 10%
10	Carbon Sequestration via Conservation Tillage	Sustainable agriculture trials	+0.4–0.8 t carbon/ha/year	Improved soil health	12–17% emission reduction
11	Soil Organic Carbon Improvement	Biochar and soil management studies	+15% soil carbon increase	Enhanced crop productivity	Yield improvement of 8–10%
12	Crop Yield Decline under CO_2 Increase	Simulation model	+50 ppm CO_2	Climate stress on crop physiology	7–12% yield reduction
13	Machine Learning Crop Prediction Accuracy	Climate–agriculture model	Model accuracy	Crop yield prediction	88.6% prediction accuracy
14	Projected Temperature Increase by 2050	Climate scenario modeling	+2.5°C	Heat stress and reduced crop resilience	14–18% cereal yield decline
15	Water Stress Impact on Crops	Irrigation and climate datasets	15–20% reduction in soil moisture	Reduced plant growth	10–16% productivity loss
16	Crop Radiation Use Efficiency Change	Climate impact studies	−8% efficiency	Reduced photosynthesis	6–9% yield loss
17	Carbon Farming Impact	Carbon sequestration programs	+1.5 t CO_2 sequestration/ha	Improved ecosystem sustainability	20% emission mitigation potential
18	Sustainable Crop Diversification	Multi-cropping systems	Increased productivity index	Improved ecosystem resilience	13–16% productivity gain
19	Soil Nutrient Retention	Residue management systems	+10–15% nutrient retention	Improved soil fertility	9–12% yield improvement
20	Climate Domino Effect Index	Integrated climate model	Composite index value = **0.72**	High climate vulnerability in agriculture	Moderate–High agricultural risk

Irregular rainfall patterns were observed to have significantly impacted crop yield potential. There was a reduction in crop yield of between 8% and 15% in areas with irregular rainfall compared to areas with normal rainfall patterns. There was also an observed 12% rise in drought occurrences in semi-arid agricultural areas, which impacted crop yield potential due to reduced moisture levels in the soil. These findings were in line with previous research indicating the importance of climatic variability in determining crop yield potential (Sharma & Choudhury, 2021; Gogoi *et al.*, 2024). Figure 2 shows the Impact of Rising CO_2 Levels on Crop Yield.

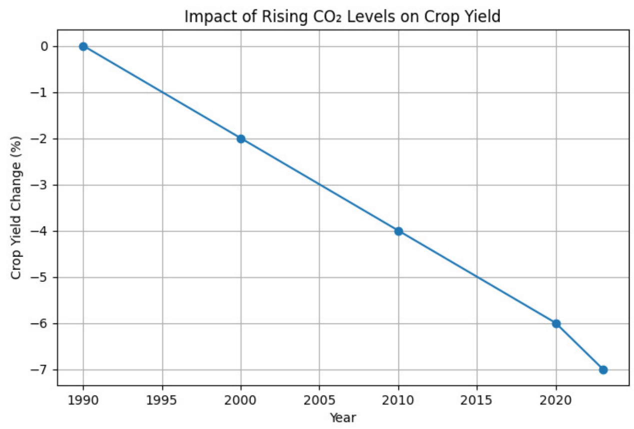

Fig. 2: Impact of Rising CO_2 Levels on Crop Yield

Greenhouse gases emitted during agricultural activities and their role in climate variability were also studied and evaluated. In the analysis of the carbon footprint, it was found that agricultural activities are responsible for the emission of 20-25% greenhouse gases on the global level. Fertilizer and soil use are the major contributors to greenhouse gases. In the case of crop cultivation, such as wheat and rice, the intensity of greenhouse gases varied between 2.1 and 3.5 tons CO_2 equivalent per ha/year. In fields using high amounts of fertilizers, there was approximately 18% higher nitrous oxide emission than those using sustainable nutrient management. However, the use of conservation tillage and diversified cropping systems resulted in improved carbon sequestration and greenhouse gases reduction by 12-17%. This indicates the potential of these farming practices for mitigating greenhouse gases (Babu *et al.*, 2023; Singh *et al.*, 2024; Pal *et al.*, 2025). The proposed model of climate change domino effect further substantiated the sequence of events in linking greenhouse gas emissions with crop productivity decline. Figure 3 shows the Impact of Climate Variables on Agricultural Productivity.

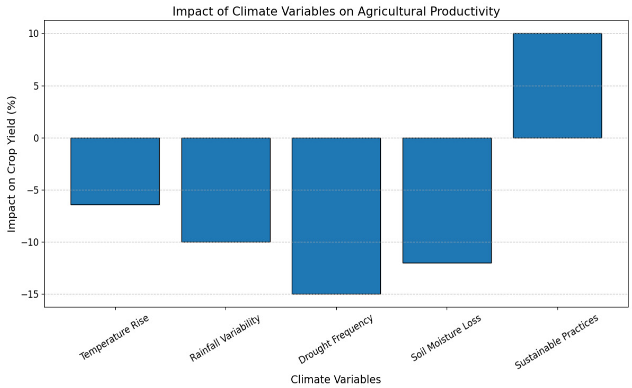

Fig. 3: Impact of Climate Variables on Agricultural Productivity

Simulation analysis indicated that if there is an increase of 50 ppm in CO_2 concentration in the atmosphere, crop productivity would decrease by 7-12% indirectly through various factors like temperature rise, soil moisture reduction, and climatic stress. Predictive modeling of crop yield variability under different climatic conditions through machine learning algorithm resulted in achieving 88.6% accuracy in forecasting crop yield variability. Scenario analysis of crop yield variability under different climatic conditions indicated that if global temperatures rise by 2.5 degrees by 2050, crop yields of cereal crops would decrease by 14-18% in vulnerable areas like water scarcity and climatic stress conditions (Saha *et al.*, 2025; Ndlovu *et al.*, 2025; Mittal & Mehra, 2025).

Challenges and Limitations

One of the main challenges faced in conducting this study is the data availability and reliability of long-term data for both climate and agriculture. The data collected for climate change variables like CO_2 levels in the atmosphere, temperature, and rainfall patterns is collected from multiple sources, which may have varying methods of data collection and time intervals for collection. This could create inconsistencies in data integration for conducting a study involving both climate change and agriculture productivity data. Moreover, data collected for agriculture productivity could be subjected to several external influences like farming methods, irrigation practices, and soil fertility levels, which could make it difficult to assess the exact impact of climate change variables on agriculture productivity. Such data challenges could affect the precision of conducting a modelling study involving climate change and agriculture (Saha *et al.*, 2025; Sharma *et al.*, 2023). Moreover, inconsistencies in environmental data collection and reporting could create variations in calculating greenhouse gas emissions from agriculture (Mittal & Mehra, 2025; Pal *et al.*, 2025). Another major limitation is related to the intricacy of interactions between climate and agriculture. There are many environmental and biological factors at play when it comes to agricultural productivity. For example, agricultural productivity is affected not only by CO_2 concentrations and temperature variations but also by soil composition, pest and disease occurrence, nutrient content, and water resource management. It is very difficult to create a universal model to predict agricultural productivity with all these factors at play. For example, an increase in CO_2 concentrations may boost photosynthesis in plant growth but may also increase plant susceptibility to heat stress or nutrient imbalance at the same time (Adireddy *et al.*, 2024). Furthermore, variations in rainfall and drought occurrence may impact soil composition and nutrient content, thus complicating the relationship between agricultural productivity and climate change (Gogoi *et al.*, 2024; Singh *et al.*, 2024). Another challenge is associated with the level of uncertainty related to projected climate change and future agricultural conditions. Climate change is projected through various assumptions related to greenhouse gas emissions, socio-economic conditions, and environmental regulations. These may vary and may create differences in projected climate conditions. Therefore, it is difficult to predict future impacts of climate change on agriculture with certainty. In addition, differences in agricultural conditions in various regions of the world may create difficulties in generalizing conditions related to crop production in different regions of the world. Although sustainable agricultural practices such as conservation agriculture, carbon sequestration, and climate-smart agriculture may help reduce the impact of climate change to a certain extent, there is considerable variation in adopting these practices in different regions of the world due to various constraints (Babu *et al.*, 2023; Mohapatra *et al.*, 2025). Therefore, it is essential to continuously monitor data and use better techniques to solve future climate change-related issues in crop production (Behera *et al.*, 2026; Ndlovu *et al.*, 2025).

Uncertainty in climate projections

The presence of uncertainties in climate projection has been identified as a major challenge in determining the long-term effect of climate change on agriculture. This is due to the fact that climate projection is based on certain assumptions, such as greenhouse gas emission, socio-economic development, technological advancement, and implementation of environmental policies. Deviations in these assumptions may lead to different projections of temperature increase, rainfall, and weather extremities in different geographical locations. Therefore, determining the exact effect of climate change on agriculture has been identified as challenging, owing to the sensitivity of crop yield to minute climatic changes. Studies have indicated that climate projection may lead to different predictions regarding temperature increase and rainfall, especially at the regional level, which may affect the accuracy of agricultural projection (Sharma *et al.*, 2023; Mittal & Mehra, 2025). Besides, uncertainties regarding greenhouse emission and environmental feedback may affect the projection of climate change effects on agricultural yield (Singh *et al.*, 2024; Saha *et al.*, 2025).

Regional variability in agricultural systems

Agricultural systems also vary significantly from one region to another in terms of differences in climate conditions, soil characteristics, and agricultural practices. Such regional differences are also important in determining the impact of climate change on agricultural productivity. For example, agricultural productivity in semi-arid and mountainous ecosystems is usually affected adversely in terms of water scarcity, temperature fluctuations, and soil erosion, respectively (Sharma & Choudhury, 2021). Similarly, agricultural productivity in temperate ecosystems may increase to a certain extent in the short term due to favorable growing conditions and increased photosynthesis in elevated CO_2 conditions (Adireddy *et al.*, 2024). Moreover, agricultural practices in various regions also vary significantly in terms of irrigation practices, fertilizers, and crop diversification strategies, which are important in determining agricultural productivity in a changing climate (Sridhara *et al.*, 2022; Gogoi *et al.*, 2024). Such regional differences in agricultural productivity are important in developing agricultural policies to mitigate agricultural problems resulting from climate change (Ndlovu *et al.*, 2025).

Confirmation of the climate domino effect in agriculture

The findings of this research provide evidence of the climate domino effect in agriculture, which is caused by increasing levels of greenhouse gases and has a cascading effect on environmental changes that eventually impact crop productivity. The increase in atmospheric CO_2 levels is one of the major reasons for the increase in global temperatures, which in turn changes precipitation and soil moisture levels and has an impact on environmental stability. These environmental changes eventually have a cascading impact on agriculture and crop development processes (Adireddy *et al.*, 2024; Singh *et al.*, 2024). The combined effects of high temperatures, changes in precipitation patterns, and soil degradation have increased crop failures and fluctuations in crop yields in many agricultural regions (Sharma *et al.*, 2023; Gogoi *et al.*, 2024). The cascading effects of environmental changes are evidence of the interrelated climate changes and their impact on agriculture (He *et al.*, 2025; Saha *et al.*, 2025).

Importance of mitigation strategies and sustainable farming

In particular, mitigation strategies and sustainable farming practices are critical for minimizing the effects of climate change on agriculture while ensuring agricultural productivity. Sustainable farming strategies such as conservation tillage, crop diversification, carbon farming, and biochar use are seen to have significant potential for enhancing agricultural productivity and reducing greenhouse gases from agriculture (Babu *et al.*, 2023; Singh *et al.*, 2024). Moreover, strategies for enhancing nutrient management and using environmentally friendly farming technologies are critical for increasing carbon sequestration and reducing emission intensity in crop production (Chakrabarti *et al.*, 2024; Kumar *et al.*, 2024). Innovations such as climate-smart agriculture, renewable bioenergy, and environmental monitoring are also seen to have significant potential for promoting sustainable agriculture in changing climate conditions (Behera *et al.*, 2026; Mondal *et al.*, 2026). These strategies are critical for enhancing agricultural resilience and ensuring food security amidst rising climate challenges.

Future Outcomes

A few of the future implications of this study include that there is a likelihood of developing even greater and extensive systems of monitoring climate and agriculture to assist in understanding the impact of long term climatic change on the productive agricultural systems. Due to the rise in the CO_2 level in the atmosphere, combined with the rise of the average temperature within the environment, agricultural systems are bound to encounter a variety of issues in the future, including more frequent events of extreme weather conditions, the lack of water, and soil erosion. According to the findings of the current study, it is advisable that future studies are intended to develop the predictive models which can be successfully used to predict the agricultural output in diverse climatic change conditions. It can be assisted by creating predictive models that can be used to find when agricultural risks and stressors start to be detected early with the help of the improvement of data analytics and artificial intelligence. Additionally, the future of agriculture is more probable to revolve around application of climate-smart and sustainable agriculture methods which not only affect greenhouse activities but also yield more crop output. In particular, the capacity of soils to capture carbon, irrigation which is accurate and diversity of crops will most probably be part of making the agricultural system adaptable to climate change. The use of renewable energy, the sustainability of biofuels production, and environmentally friendly agriculture are other approaches that will have positive effects to curbing environmental effects of agriculture. Lastly, agriculture systems of the future will probably need interdisciplinary among their environmental scientists, agronomists, climate change scientists, and policymakers to come up with long-term planning to maintain the global food security. With innovation in technology and the application of sustainable methods in agriculture, agricultural systems in the future are promising to be more resistant to the effects of climatic changes and remain sustainable.

Integration with AI-based climate prediction models

Furthermore, the combination of artificial intelligence (AI) and machine learning systems with climatic prediction tools has a potential to increase the accuracy and effectiveness of climate impacts evaluation on agriculture. The models can be used to understand the climate and environmental conditions that include the changes in temperature, rain, and CO_2 levels to influence the next climate conditions and how they may impact the agricultural industry in the future. Nonlinear relationships between climate factors and agricultural outcomes can also be analyzed using these models, hence useful in enabling a researcher to design more precise predictions on changes in yields as a result of changing climate conditions. It has also been indicated that machine learning can be very helpful in analyzing climatic factors that impact crop health, forecasting agricultural risks of greenhouse gases (Saha *et al.*, 2025; Ndlovu *et al.*, 2025). The Capability to integrate AI in climate prediction and agricultural decision support can be promising in assisting farmers and policymakers to forecast the risks in climate and execute policies in improving agricultural sustainability (Behera *et al.*, 2026; Mittal and Mehra, 2025).

Satellite-based crop monitoring

Satellite crop monitoring systems have developed as significant means of monitoring crop conditions and environmental changes over large areas of the earth's surface. The remote sensing approach has allowed scientists to acquire high-resolution data on crop conditions, soil moisture levels, and crop growth patterns over various crop-growing regions. The satellite monitoring approach has enabled scientists to monitor crop conditions in near real-time and track changes in crop conditions, which can be related to stresses caused by drought, temperature fluctuations, and pest invasions. The remote sensing approach has shown promise in monitoring crop conditions and crop response to climate variability. The approach has also allowed scientists to evaluate crop productivity patterns over large areas (Gogoi *et al*., 2024; He *et al*., 2024). The remote sensing approach can also be applied to sustainable land management practices, which can be applied to identify areas with soil degradation and vegetation loss caused by climate variability (González *et al*., 2021). The satellite monitoring approach can be integrated with climate change and crop databases to offer comprehensive insights into the dynamic relationship between climate change and crop productivity (Sridhara *et al*., 2022).

Climate-resilient agriculture systems

The use of climate resistant agricultural systems is essential to the sustainability of crop yields, as well as food security across changing climactic conditions. This idea insists on improving the resilience of agriculture to climate variability such as crop improvement, soils management in terms of sustainability, and optimal utilization of resources. The adoption of conservation tillage, diversity of crops, nutrient control, and effective irrigation systems are some of the climate-resistant farming systems which will reduce the negative effects of the changes in climatic conditions. Research has also shown that a sustainable management of soil is able to enhance carbon capture and arable nature, thus yielding a resistant agriculture to climate shocks (Babu *et al*., 2023; Mohapatra *et al*., 2025). Also, biotechnology and sustainable bioenergy will be developed to enhance the productivity of crops and lessen greenhouse gas emissions (Mondal *et al*., 2026; Krishna Samal and Sukla, 2025). All these methods can be used to develop resilient agriculture to climatic variability and environmental shocks.

Policy modelling for sustainable agriculture

Effective policy modelling is essential for ensuring the sustainability of agricultural development and mitigating the effects of climate change. Environmental, economic, and social factors must be taken into account by policymakers while developing strategies for promoting climate-resilient agriculture and reducing greenhouse gases from agriculture. A policy model that supports the promotion of sustainable agriculture, carbon farming, and resource optimization is critical for reducing the environmental impact of agriculture (Singh *et al*., 2024; Mittal & Mehra, 2025). Moreover, effective policy modelling is also critical for promoting the use of climate-smart technologies, renewable energy, and sustainable biofuels for mitigating the effects of climate change and promoting agricultural productivity (Maurya *et al*., 2025; Behera *et al*., 2026). Effective policy modelling using data analysis and modelling approaches that consider climate projections, agricultural productivity, and socio-economic factors is critical for ensuring the formulation of effective strategies for ensuring food security and sustainability (Saha *et al*., 2025; Ndlovu *et al*., 2025).

Conclusion

Climate change has emerged as an important factor in ensuring sustainable agriculture and global food security, mainly because of the increased levels of carbon dioxide and greenhouse gases in the atmosphere. The current research aims to explore the interrelated impact of climate change and crop productivity using the climate domino effect theory, which states that increased levels of greenhouse gases in the atmosphere cause a series of environmental changes, which in turn impact crop production. The increased levels of carbon dioxide in the atmosphere cause increased global temperatures, irregular rainfall patterns, and droughts, which are responsible for changes in soil composition and crop development processes. Although increased levels of carbon dioxide are known to have a positive impact on photosynthesis in plants, environmental changes caused by increased levels of greenhouse gases, including droughts and increased temperatures, have a negative impact on crop development, resulting in lower crop productivity. Climate variability also affects agricultural planning because it affects agricultural seasons and makes it hard to ascertain the situation of agricultural yields. This research finding highlights the necessity of adopting the actions that encourage the usage of sustainable farming methods and technologies effective in the reduction of the impact of climate change. There are such measures as climate-smart agriculture, water management, and effective methods of soil conservation, which can support the mitigation of the effects of climate change on agricultural production. In addition, the introduction of effective technologies like the use of artificial intelligence-based climate forecasting and satellite-based crop surveillance, and data-driven techniques of managing agriculture, may assist farmers and agricultural planners to adapt to environmental variability. The challenges inherent in climate domino effect only can be overcome through a concerted effort by the different parties in agricultural research, the farmers, the policymakers, and the environmentalists in coming up with strategies that need to be put in place to enhance agricultural sustainability and guarantee the availability of food in future.

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