

Climate change and its impact on agriculture

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Abstract

Climate change is a global phenomenon that poses significant challenges to various sectors including agriculture. As the Earth's climate undergoes unprecedented changes due to human activities, the implications for agricultural systems and food production are profound. Rising temperatures, altered precipitation patterns and more frequent extreme weather events are transforming the agricultural landscape and posing risks to global food security. In this context, this discussion will delve into the impact of climate change on agriculture, focusing on how changing climatic conditions affect crop production, food availability and the livelihoods of farming communities.

We will explore the specific challenges posed by climate change, the vulnerabilities of agricultural systems and the measures needed to build resilience and ensure sustainable food production in the face of a changing climate. By comprehending the intricacies of climate change and its impact on agriculture, we can foster awareness, drive policy changes and promote practices that promote the long-term sustainability and resilience of agricultural systems. Through collective action and innovative approaches, it is possible to navigate the challenges posed by climate change and secure a future where agriculture can thrive amidst a changing climate.

Keywords: Climate change, Greenhouse effect, Greenhouse gases, Global warming, Governmental, Global health.

Introduction

Climate change is among the most crucial concerns of the world. It is a serious threat to the global agriculture and its overall impact on global agriculture is yet not clear. A rise of 2.5-4.5°C is expected in the global temperature until the end of 21st century.¹¹

Climate change is a global threat to the food and nutritional security of the world⁸. Climate change presents real threats to agricultural production, forest resources and rural economies. These threats have significant implications not just for farmers, ranchers and forest landowners, but for all people.

Land managers across the country are already feeling the pressures of a changing climate and its effects on weather. The effects of climate change on agriculture can result in lower crop yields and nutritional quality due to drought, heat waves and flooding as well as increases in pests and plant diseases.

Incorporating climate-smart farming methods is one way to reduce the impact of climate change on agriculture. Climate change impacts on agriculture are multifaceted and encompass diverse aspects such as crop yields, water availability, pest and disease dynamics and overall agricultural productivity. These impacts vary across regions, but no country is immune to the consequences of a changing climate. Understanding the intricate relationship between climate change and agriculture is essential for developing effective strategies to mitigate and adapt to its effects.

Climate change also affects an ecosystem directly or indirectly. Changes in climate will affect the groundwater recharge, water cycle, soil moisture, livestock and aquatic species. Changes in climate increase the incidence of pests and diseases which cause a huge loss in crop production. Due to climate change, deterioration in soil fertility, promoting salinity, defiance of many pesticides, herbicides and deterioration of irrigation water quality should be found.

Global scenario of climate change

Global climate change characterized by an increase in temperature has become the focus of attention all over the world¹⁰. The global scenario of climate change refers to the overall picture of climate change on a planetary scale. Here are some key aspects of the global scenario of climate change:

Rising temperatures: Global temperatures have been increasing over the past century, with the warmest years on record occurring in recent decades. The Intergovernmental Panel on Climate Change (IPCC) states that human activities, particularly the burning of fossil fuels and deforestation, are the primary drivers of this temperature rise.

Extreme weather events: Climate change has led to an increase in the frequency and intensity of extreme weather events. These include heatwaves, droughts, floods, hurricanes and wildfires. The impacts of these events can be devastating, causing loss of life, damage to infrastructure, displacement of communities and disruptions to ecosystems and economies.

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Sea-level rise: As a result of global warming, sea levels are rising due to the melting of glaciers and ice sheets, as well as the expansion of seawater as it warms. Rising sea levels pose significant risks to coastal areas including increased coastal erosion, saltwater intrusion into freshwater sources and increased vulnerability to storm surges and coastal flooding.

Ocean acidification: The increase in atmospheric carbon dioxide (CO₂) due to human activities is causing the oceans to absorb more CO₂. This leads to ocean acidification which negatively impacts marine ecosystems including coral reefs, shellfish and other marine organisms that rely on carbonate ions for shell and skeletal formation.

Biodiversity loss: Climate change is a significant driver of biodiversity loss globally. Changing temperatures and altered precipitation patterns disrupt ecosystems and impact the distribution and behavior of species. This can lead to habitat loss, species extinction and disruptions in ecological balance and ecosystem services.

International agreements and initiatives: The global community has recognized the need to address climate change and has taken several international initiatives. The Paris agreement, adopted in 2015, aims to limit global warming well below 2°C above pre-industrial levels and pursue efforts to limit the temperature increase to 1.5°C. Countries are expected to submit Nationally Determined Contributions (NDCs) outlining their efforts to reduce greenhouse gas emissions and adapt to climate change.

It is important to note that the impacts of climate change are not uniform globally, with some regions more vulnerable than others due to factors such as geographic location, socio-economic conditions and existing infrastructure. However,

addressing climate change requires global cooperation and collective action to reduce greenhouse gas emissions, promote sustainable practices, enhance resilience and mitigate the impacts of climate change on communities and ecosystems worldwide.

Climate change scenarios or socioeconomic scenarios are projections of future greenhouse gas (GHG) emissions used by analysts to assess future vulnerability to climate change.¹ Scenarios and pathways are created by scientists to survey any long term routes and explore the effectiveness of mitigation and help us understand what the future may hold, this will allow us to envision the future of human environment system.² Producing scenarios requires estimates of future population levels, economic activity, the structure of governance, social values and patterns of technological change. Economic and energy modelling (such as the World3 or the POLES models) can be used to analyse and quantify the effects of such drivers.

Indian scenario of climate change

India is ranked fourth among the list of countries most affected by climate change in 2015³. Since the middle of the twentieth century, India has witnessed a rise in average temperature, a decrease in monsoon precipitation, a rise in extreme temperature and rainfall events, droughts and sea levels; and an increase in the intensity of severe cyclones alongside other changes in the monsoon system⁴. In a worst-case scenario, average surface air temperatures over India could rise by up to 4.4°C by the end of the century as compared to the period between 1976 and 2005⁵. India has submitted updated climate change pledges to the UN based on commitments made by it under the Paris agreement. India has committed to achieving net-zero emissions by 2070^{6,7}.

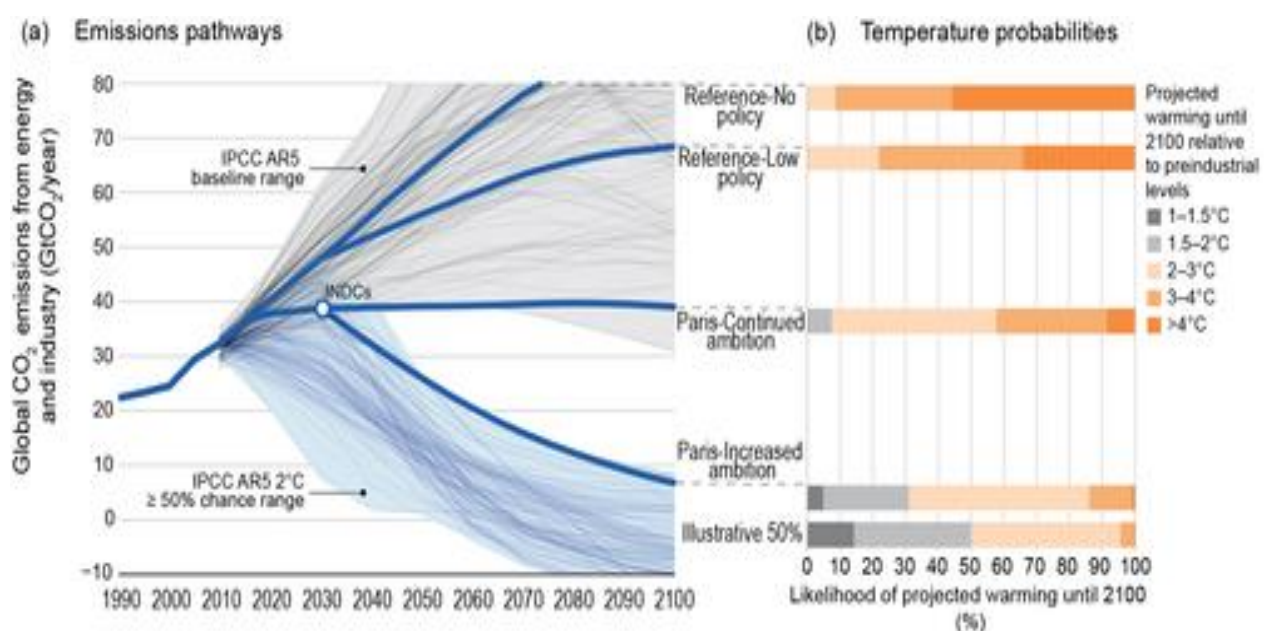


Figure 1: Global CO₂ emissions and probabilistic temperature outcomes of different policies

Source: https://en.wikipedia.org/wiki/Climate_change_scenario

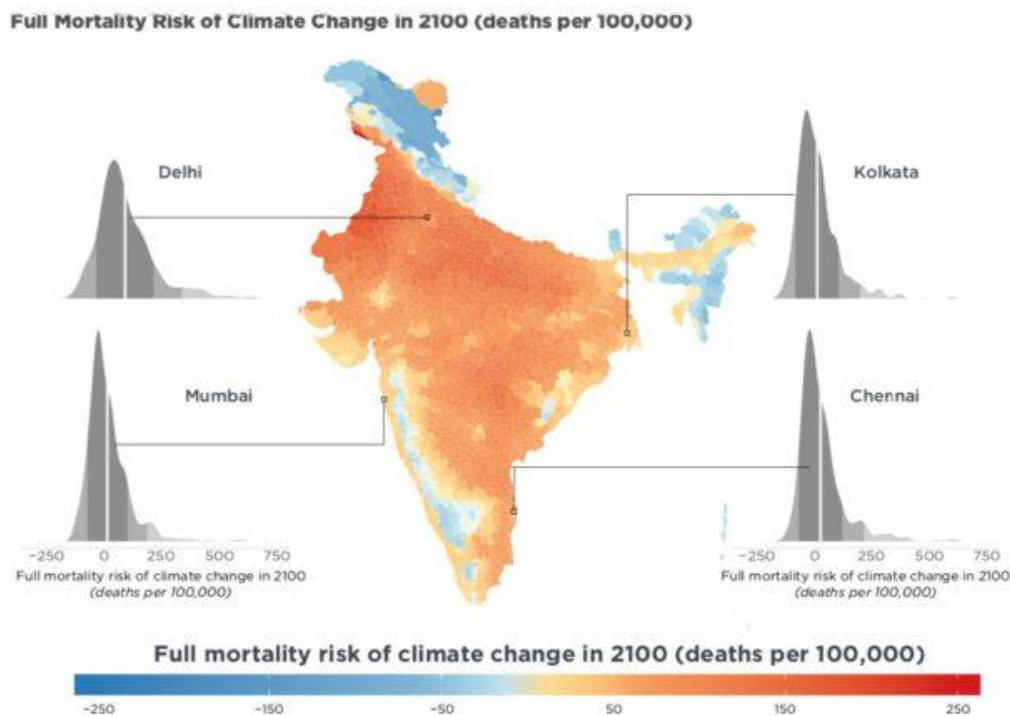


Figure 2: Climate change in India

Source: <https://newsvibesofindia.com/climate-change-in-india-to-kill-1-5-mn-per-year-from-2100-study/>

In a high-emission scenario, the national capital of the country is projected to see 22 times more extremely hot days and more than 23,000 deaths caused by climate change per year from 2100. However, Odisha is projected to top the list when it comes to the highest increase in the number of extremely hot days, rising from 1.62 in 2010 to 48.05 by 2100. Punjab is expected to continue to be India's hottest State in 2100, with an average annual temperature around 36°C.¹⁸

The Indian scenario of climate change is characterized by a range of environmental and socio-economic challenges. India is highly vulnerable to the impacts of climate change due to its large population, dependence on agriculture and extensive coastal areas. Here are some key aspects of the Indian scenario of climate change:

Temperature rise: India has experienced a significant increase in average temperatures over the past few decades. Heatwaves have become more frequent and intense, posing risks to human health, particularly for vulnerable populations such as the elderly and outdoor workers.

Monsoon patterns: India's agriculture heavily relies on the monsoon season which brings rainfall crucial for crop growth. Climate change has affected monsoon patterns leading to increased variability, erratic rainfall and changes in the timing and intensity of monsoons. These changes have implications for agriculture, water availability and food security.

Glacial retreat: The Himalayan glaciers are a vital source of freshwater for several major rivers in India. Climate

change has accelerated glacial melt, posing risks of glacial lake outburst floods, water scarcity and downstream impacts on river systems. This has implications for agriculture, hydropower generation and water resources.

Sea-level rise and coastal vulnerability: India has a long coastline and many densely populated coastal areas at risk from sea-level rise. Coastal erosion, saltwater intrusion and increased frequency of extreme weather events like cyclones, threaten coastal communities, infrastructure and ecosystems.

Biodiversity loss: Climate change affects India's rich biodiversity, including its forests, wildlife and marine ecosystems. Changes in temperature and precipitation patterns can disrupt ecosystems, alter species distributions and lead to habitat loss. This loss of biodiversity has broader implications for ecological balance, livelihoods and ecosystem services.

Adaptation and mitigation efforts: The Indian government has recognized the importance of addressing climate change and has taken several steps toward adaptation and mitigation. These include the implementation of renewable energy projects, efforts to enhance energy efficiency, afforestation initiatives and the National Action Plan on climate change. However, significant challenges remain in implementing these measures effectively. It is important to note that the Indian scenario of climate change is complex and multifaceted, with diverse regional variations. Localized impacts such as water scarcity in certain regions or changing disease patterns, also contribute to the overall scenario.

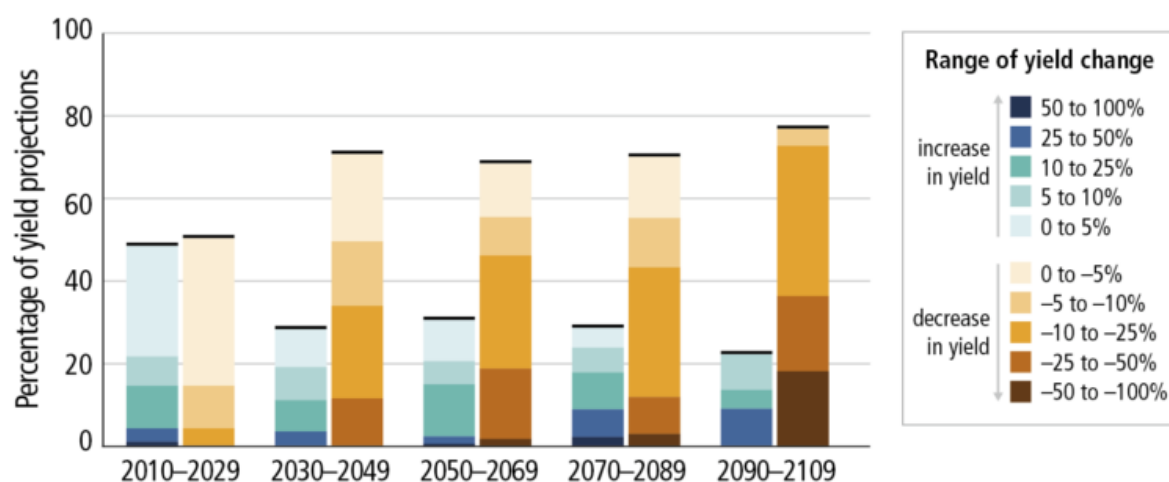


Figure 3: Range of yield change

Source: <https://www.futurelearn.com/info/courses/climate-smartagriculture/0/steps/26565>

Ongoing research, policy interventions and international collaborations are essential to address the challenges posed by climate change in India.

Impact of climate change on global agriculture

Agriculture is strongly influenced by weather and climate. While farmers are often flexible in dealing with weather and year-to-year variability, there is nevertheless a high degree of adaptation to the local climate in the form of established infrastructure, local farming practice and individual experience. Climate change can therefore be expected to impact on agriculture, potentially threatening established aspects of farming systems but also providing opportunities for improvements⁹. Climate change has significant and far-reaching impacts on world agriculture, affecting crop yields, food production and global food security. Here are some key impacts of climate change on agriculture worldwide:

Agriculture and the wider food production system, is already a major source of Greenhouse gas emissions. Future intensification of agriculture to compensate for reduced production (partly caused by climate change) alongside an increasing demand for animal products, could further increase these emissions. It is estimated that the demand for livestock products will grow by +70% between 2005 and 2050.¹⁶

Reduced crop yields: Rising temperatures, heatwaves and changes in precipitation patterns can lead to reduced crop yields. Heat stress during critical growth stages can damage crops and decrease photosynthesis, resulting in lower productivity. Changes in rainfall patterns including droughts or erratic rainfall, can cause water stress and hinder crop growth, leading to reduced yields and crop failures.

Shifts in crop suitability: Climate change can alter the suitability of certain crops in different regions. Changes in temperature and rainfall patterns may make some areas less suitable for traditional crops, while other regions may

become more favorable for different crops. This can necessitate shifts in crop choices, altered planting schedules and changes in farming practices to adapt to the changing climate conditions.

Water availability and irrigation challenges: Climate change influences water availability which is crucial for agriculture. Changes in precipitation patterns including droughts or excessive rainfall, can result in water scarcity or waterlogging, affecting irrigation practices. Limited water availability can reduce crop water uptake, leading to water stress and decreased yields.

Increased pest and disease pressure: Climate change can affect the population dynamics and geographical distribution of pests and diseases, posing challenges to agriculture. Warmer temperatures can favor the proliferation of pests such as insects and weeds, leading to increased infestations and crop damage. Changes in rainfall patterns can also create conditions favorable for the spread of diseases, impacting crop health and productivity.

Impacts on food security: Climate change poses risks to global food security. Extreme weather events such as droughts, floods and storms, can cause crop failures and disruptions in food supply chains. This can result in food price volatility and reduced access to nutritious food, particularly for vulnerable populations. Climate change impacts on agriculture can undermine food security and exacerbate existing inequalities.

Socioeconomic implications: The impacts of climate change on agriculture have broader socio-economic consequences. Agricultural-dependent communities and small-scale farmers, particularly in developing countries, are disproportionately affected. Reduced crop yields and income can lead to increased poverty, migration and social unrest. The economic stability of countries heavily reliant on agriculture can also be at risk.

The impacts of climate change on world agriculture require a comprehensive approach including implementing adaptive and resilient agricultural practices, promoting sustainable water management, developing climate-resilient crop varieties, improving pest and disease management strategies and supporting farmers with information, resources and financial incentives. International collaborations, research and policy interventions are vital in ensuring sustainable food production, enhancing global food security and building resilience in the face of climate change.

Impact of climate change on India's agriculture

Climate change is adversely affecting the Indian agricultural sector,¹³ particularly vulnerable to the impacts of climate change due to its heavy reliance on monsoon rains and the large population engaged in agriculture. Here are some key impacts of climate change on India's agriculture:

Erratic monsoon patterns: The monsoon is critical for India's agriculture as it provides water for irrigation and determines planting and harvesting schedules. Climate change has led to increased variability in monsoon patterns including altered onset, duration and intensity of rainfall. Unpredictable and erratic monsoons can result in droughts or excessive rainfall, leading to water scarcity or waterlogging, both of which can adversely affect crop production.

Water stress and irrigation challenges: Climate change impacts water availability, which is crucial for agricultural productivity. Changes in precipitation patterns, coupled with increased evaporation rates due to higher temperatures, can result in water stress and shortages for irrigation. This can limit farmers' ability to adequately irrigate their crops, leading to reduced yields and crop failures.

Heat stress on crops: Rising temperatures associated with climate change increase the risk of heat stress on crops. Heatwaves during critical growth stages can damage crops, reduce photosynthesis and impact fruiting, leading to lower yields. Heat stress can be particularly detrimental to crops like wheat, rice, maize and vegetables.

Increased frequency of extreme weather events: Climate change has led to an increase in the frequency and intensity of extreme weather events in India such as droughts, floods, cyclones and storms. These events can cause substantial damage to crops, soil erosion, loss of livestock and infrastructure destruction. Farmers face challenges in recovering from such events and rebuilding their livelihoods.

Shifting crop suitability: Climate change can alter the suitability of certain crops in different regions of India. Changes in temperature and rainfall patterns may render some areas less suitable for traditional crops, while other regions may become more favorable for different crops. This

requires farmers to adapt by shifting crop choices and adopting new varieties or farming practices.

Increased pest and disease pressure: Climate change can impact the population dynamics and geographical distribution of pests and diseases. Warmer temperatures can favor the proliferation of pests and increase pest pressure on crops. Changes in rainfall patterns can also create conditions favorable for the spread of diseases, leading to crop damage and reduced yields.

Agriculture

The history of agriculture has involved repeatedly overcoming constraints and achieving greater food production by increasing the amount of cultivated land and intensifying cultivation by adopting new agricultural technologies. The quantity and nutritional quality of agricultural production ultimately depend on a dynamic balance of appropriate biophysical resources including soil quality, water availability, sunlight, CO₂, temperature suitability and in some cases, pollinator abundance. Production diminishes under certain weather extremes as well as from pests, pathogens and air pollution (e.g. tropospheric ozone). In some places, production is heavily dependent on physical agricultural labour. Climate change is expected to influence each of these dimensions of agricultural production, but often in ways that remain poorly characterized.¹⁵

Climate change and agriculture

Change in climate is mainly attributed to the unabated increase in greenhouse gases including fluorinated gases, carbon dioxide, methane and nitrous oxide, which bring changes in rain pattern, temperature and negative effects on water and land resources, floods and droughts. Climate change is a global phenomenon.¹² Climate change has significant implications for agriculture, impacting crop yields, water availability, pests and diseases and overall food security. Here are some key points regarding the relationship between climate change and agriculture:

Changing growing conditions: Climate change brings shifts in temperature and precipitation patterns, which directly affect agricultural productivity. Rising temperatures can lead to heat stress in crops, reduced photosynthesis and decreased yields. Changes in rainfall patterns, including more frequent droughts or heavy rainfall events, can disrupt planting and harvesting schedules, reduce water availability and increase soil erosion.

Water availability: Climate change affects water resources which are essential for agricultural activities. Changing precipitation patterns can result in water scarcity or excess water, both of which pose challenges for crop irrigation and management. Decreased snowpack and glacial melt can also impact water availability for irrigation during the dry season, particularly in regions dependent on meltwater.

Shifts in crop suitability: As climate conditions change, the suitability of certain crops in specific regions may also change. Some regions may become unsuitable for traditional crops due to increased heat or changing rainfall patterns while other areas may become more favorable for new crops. This requires farmers to adapt and adjust their crop choices and farming practices.

Pests and diseases: Climate change can influence the distribution and abundance of pests and diseases, affecting agricultural productivity. Warmer temperatures and altered rainfall patterns can create favorable conditions for the proliferation of pests such as insects and weeds and the spread of diseases. This may lead to increased pesticide use and additional challenges in managing crop health.

Food security: Climate change poses risks to global food security. As extreme weather events become more frequent and intense, they can cause crop failures, disruptions in food supply chains and price volatility. Vulnerable populations, particularly in developing countries, are at a higher risk of food insecurity and malnutrition due to climate change impacts on agriculture.

Adaptation and mitigation: Adaptation strategies in agriculture aim to reduce vulnerability and enhance resilience to climate change. This includes the development and adoption of climate-smart agricultural practices such as improved water management, crop diversification, conservation agriculture and agroforestry. Mitigation efforts focus on reducing greenhouse gas emissions from agricultural activities such as through improved fertilizer and manure management, renewable energy use and carbon sequestration in soils.

The impacts of climate change on agriculture require a comprehensive approach involving scientific research, policy interventions, farmer education and support and international collaboration. It is crucial to promote sustainable agricultural practices that enhance resilience, conserve natural resources and contribute to global efforts in mitigating climate change.

Climate change impact on crop production

2030 Agenda for Sustainable Development adopted by all United Nations Member States in 2015 deals with 17 Sustainable Development Goals.¹⁴ Climate change has profound and varied impacts on crop production, which can significantly affect global food security. Here are some key ways in which climate change impacts crop production:

Changing temperature patterns: Rising temperatures associated with climate change can directly affect crop growth and development. Extreme heat and heatwaves can reduce photosynthesis, impair reproductive processes such as pollination and cause heat stress in crops, leading to lower yields. Heat stress can be particularly detrimental to staple crops like wheat, maize, rice and soybeans.

Altered precipitation patterns: Changes in precipitation patterns including increased frequency of droughts, floods, or erratic rainfall, can have detrimental effects on crop production. Droughts can cause water stress, impacting crop growth and yield potential. Conversely, heavy rainfall events can lead to waterlogging, soil erosion and nutrient leaching, affecting root health and nutrient availability.

Water availability and irrigation challenges: Climate change can affect water availability for irrigation, a critical factor for crop production. Changes in rainfall patterns, coupled with increased evaporation rates due to higher temperatures, can result in water scarcity. This can limit farmers' ability to irrigate their crops adequately, leading to reduced yields and crop failures.

Increased pest and disease pressure: Climate change can influence the population dynamics and geographical distribution of pests and diseases, posing challenges to crop production. Warmer temperatures can favor the proliferation of certain pests such as insects and weeds leading to increased infestations and crop damage. Changes in rainfall patterns can also create conditions conducive to the spread of diseases.

Shifts in cropping suitability and agricultural regions: Climate change can alter the suitability of certain crops in their traditional growing regions. Changes in temperature and precipitation patterns may make current agricultural areas less suitable for certain crops, while other regions may become more favorable. This necessitates adaptation measures such as shifting crop choices, adjusting planting dates and exploring new farming practices.

Impacts on crop quality and nutritional content: Climate change can also affect the nutritional quality of crops. Rising carbon dioxide (CO₂) levels can lead to reduced protein content in some crops, affecting their nutritional value. Additionally, extreme weather events and changes in growing conditions can impact crop quality attributes such as taste, texture and storage characteristics. The impacts of climate change on crop production require a combination of adaptation and mitigation strategies. These may include developing and promoting climate-resilient crop varieties, improving water management and irrigation efficiency, implementing integrated pest management approaches, investing in climate-smart agricultural practices and supporting farmers with information, resources and financial incentives. International collaborations and policy interventions are essential to ensure sustainable and resilient food production in the face of climate change.

Estimating the global yield response to climate change

Impacts of temperature change on yields of four major crops were studied based on a meta-analysis of 1010 point-estimates from 56 studies.

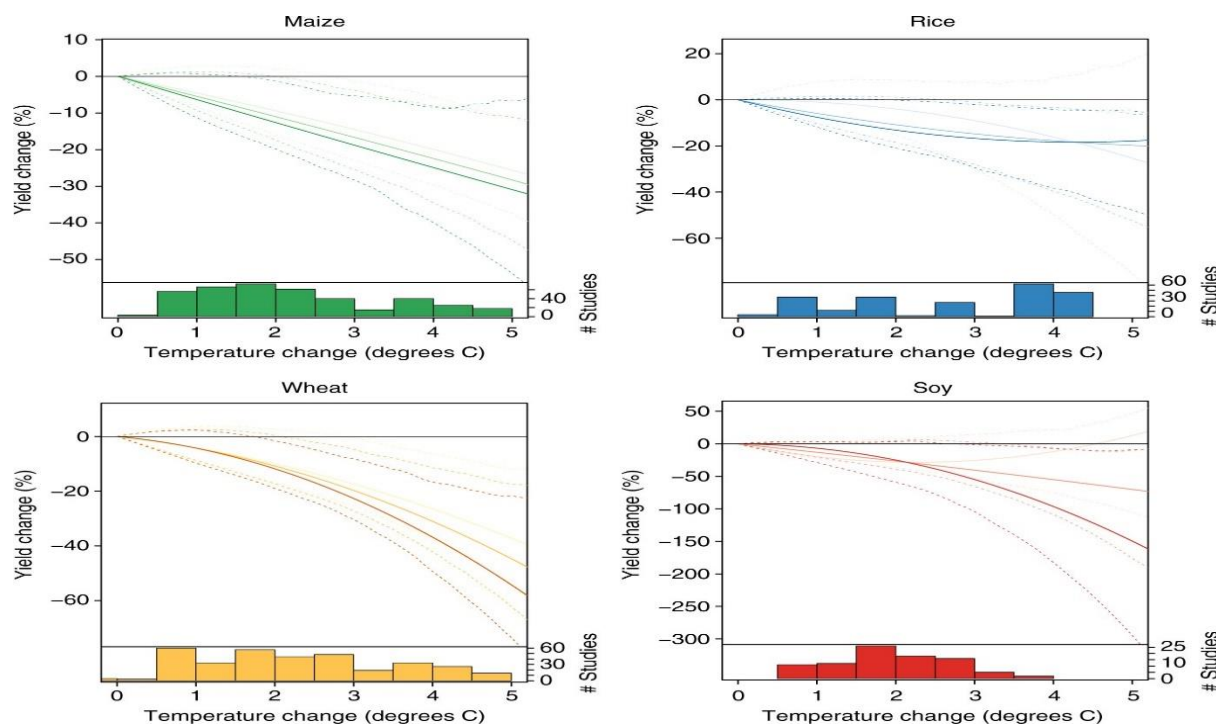


Figure 4: Impacts of temperature change on yields

Source: <https://www.nature.com/articles/s41467-017-01792-x#MOESM1>

Darkest, middle and lightest lines show responses at the 75th, 50th and 25th quantiles of baseline growing-season temperature respectively. Dashed lines show the 95% confidence interval based on 750 block bootstraps, blocking at the study level. Plotted response curves are for temperature only and do not include CO₂ fertilization or adaptation. Temperature changes are relative to a local 1995–2005 baseline. The histograms show the number of observations by crop and level of warming used to estimate the response functions. In subsequent analyses, yield losses >100% are set to losses of 99%.¹⁷

Conclusion

Climate change, the result of the “Global Warming,” has now begun displaying its impacts internationally. The climate is the primary determinant of agricultural productivity which immediately affects food manufacturing throughout the globe. The agriculture region is the touchiest zone for climate trade because the weather of a location/country determines the nature and characteristics of flora and vegetation. An increase within the suggested seasonal temperature can reduce the duration of many plants and consequently lessen final yield. Food production structures are extremely sensitive to climate changes like modifications in temperature and precipitation, which may cause outbreaks of pests and illnesses, thereby decreasing harvest and ultimately affecting the food safety of the nation.

The Internet's impact on food safety will rely upon the publicity of international environmental trade and the potential to address and recover from international environmental change. Coping with the effect of climate alternate on agriculture would require cautious control of

sources like soil, water and biodiversity. To cope with the impact of climate alternate on agriculture and food production, we have to act at the global, regional, national and local levels.

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