Impact of Climate Change on Agricultural Yields

Final Project

Qasim Ansari and Sarah DeSena

2024-12-18

Introduction

Agriculture is one of the most significant parts of the global economy, as it provides food and other necessities to people worldwide. Climate change has posed new and variable threats to agriculture, which has severely affected crop production and food security. Temperature increases, variations in rainfall, and severe weather conditions, including drought, flood, and storms, have affected the agricultural productivity of many areas. These climate change risks have the potential to destabilize crop yields, which restricts farmers' ability to anticipate and respond to fluctuations in crop growth. Since food production is a basic aspect of the agricultural sector, it is important to analyze the effects of climate change on crop yields and how these vary across different territories and circumstances to outline possible solutions to the problem. Therefore, it is crucial to examine these issues to anticipate future challenges and safeguard global food security.

In this report, I'll look at how climate change is affecting agricultural production by asking essential questions. These include the impacts of temperature on agricultural yields in different regions, the impact of extreme weather events like droughts and floods on the production of crops, and whether changes in temperature or precipitation have a greater impact on crop yields. In addition, I will investigate how crop yields have changed throughout time in response to shifting climate patterns. This paper will begin with a review of the relevant literature on climate change and its impact on agriculture. I'll then outline the research methodologies utilized to address these questions, followed by a presentation of the results. Finally, I will discuss the results and their implications for agricultural practices, future food security, and potential strategies for adapting to climate change.

Review

Research has shown that climate change significantly impacts agricultural productivity, particularly through rising temperatures, changing precipitation patterns, and extreme weather events like droughts and floods. For example, studies such as those by Lobell et al. (2011) have highlighted how increased temperatures directly reduce crop yields, especially in regions already facing water shortages. In the United States, the Midwest's maize production is expected to decline due to heat stress, while regions like India and Pakistan face similar challenges with reduced rainfall and higher temperatures, threatening food security. Extreme weather events like droughts in Australia, heatwaves, and floods in Thailand further disrupt crop production, emphasizing the vulnerability of agriculture to climate change.

Additionally, changes in precipitation can have a more significant impact than temperature changes in some regions. Mendelsohn et al. (2006) found that water stress from altered rainfall patterns is particularly harmful to crops like corn in the U.S. and rice in China. As climate change continues to affect crop yields, the Intergovernmental Panel on Climate Change (IPCC, 2019) predicts that productivity will decrease, especially in low-latitude regions. Countries like India are already seeing more unpredictable monsoons, affecting key crops like rice and wheat. Shifting growing seasons and crop patterns, such as those observed in China, highlight the need for agricultural practices to adapt to these new climate realities.

Prior Investigations of the Impact of Climate Change on Agricultural Yields

Climate change, particularly fluctuations in temperature and rainfall, has a profound effect on agriculture and crop yields. While food prices have generally decreased over the past century due to increased agricultural productivity, recent climate-related events such as droughts in Australia and heatwaves in Russia have caused significant price hikes. These disruptions underscore the growing concern about how rising global temperatures are affecting food production. This article examines the impacts of recent climate trends on key crop yields.

David B. Lobell, Wolfram Schlenker, and Justin Costa-Roberts conducted a study to assess how climate trends have influenced the global yields of maize, wheat, rice, and soybeans from 1980 to 2008. The researchers analyzed data on crop production, growing seasons, locations, and monthly climate variables. They found that global temperatures have increased by 0.13°C per decade since 1950, with projections suggesting an acceleration to 0.2°C per decade. This warming trend has significantly impacted crop-growing regions, while changes in precipitation have been smaller and more inconsistent. The study also highlights regional variations in crop responses. For example, U.S. maize production remained largely unaffected due to slight cooling, but countries like Russia and Mexico saw declines in crop yields. Overall, rising temperatures have negatively impacted maize and wheat yields, with Russia's wheat yields

decreasing by 4.9%. Meanwhile, rice and soybean yields showed mixed results, with rice remaining stable due to opposing regional climate effects.

While the study offers a detailed statistical analysis of climate trends and their effects on major crops, it does have limitations. It does not fully account for long-term adaptation strategies by farmers, such as switching crops or using new technologies. Additionally, the study overlooks the disproportionate impact of extreme weather events, such as heatwaves and droughts, which can be more damaging than gradual temperature changes. Though the study acknowledges regional differences, its models assume that adaptation occurs uniformly across countries, which may not reflect the unique socio-economic and agricultural factors that shape resilience in different regions. Using panel regression analysis, the study identifies temperature as the most significant factor affecting crop yields. Warmer conditions tend to benefit some crops, such as rice in high-latitude areas, while others, like wheat, suffer declines.

The findings reveal that rising temperatures have had a significant impact on maize and wheat yields, with global production losses of 3.8% and 5.5%, respectively. In contrast, rice showed some regional gains, especially in high-latitude regions, while soybeans experienced minimal impact. These results align with earlier research that highlights the negative effects of climate change on wheat and maize yields in regions like India and France, while confirming that rice yields are less sensitive to temperature changes alone.

Global Production and Yield Impact of Climate Trends (1980–2008)

Crop	**Global Production (1998–2002 Average, Million Metric Tons)**	**Global Yield Impact of Temperature Trends (%)**	**Global Yield Impact of Precipitation Trends (%)**	**Subtotal Global Yield Impact (%)**	**Global Yield Impact of CO2 Trends (%)**	**Total Global Yield Impact (%)**
Maize	607	-3.1 (-4.9, -1.4)	-0.7 (-1.2, 0.2)	-3.8 (-5.8, -1.9)	0.0	-3.8
Rice	591	0.1 (-0.9, 1.2)	-0.2 (-1.0, 0.5)	-0.1 (-1.6, 1.4)	3.0	2.9
Wheat	586	-4.9 (-7.2, -2.8)	-0.6 (-1.3, 0.1)	-5.5 (-8.0, -3.3)	3.0	-2.5
Soybean	168	-0.8 (-3.8, 1.9	-0.9 (-1.5, -0.2)	-1.7 (-4.9, 1.2)	3.0	1.3

Figure 1. Global Impacts of Climate Trends on Crop Yields (1980–2008) Data from Lobell, Schlenker, and Costa-Roberts (2011)

The data reveals that rising temperatures significantly reduced global maize, and wheat yields by 3.8% and 5.5%, respectively, while changes in precipitation had a smaller effect. In contrast, rice yields showed a slight increase, particularly due to the benefits of rising CO2 levels, resulting in a 2.9% yield increase. Soybean yields experienced a modest gain of 1.3%, also due to CO2 trends. Temperature was the dominant factor driving yield changes, especially for maize and wheat, while precipitation had a minor effect. CO2 trends helped offset some of the losses for most crops, highlighting the differing sensitivity of various crops to climate change.

The study underscores the significant impact of climate change on global crop yields and provides a framework for understanding how key crops like maize, wheat, rice, and soybeans are affected by climate trends. However, it also points to the need for further research that incorporates farmers' adaptation strategies, such as switching crops or adopting new technologies, as well as the effects of extreme weather events like heatwaves and droughts, which are not fully captured in the current models. Addressing these gaps will be essential for better understanding how climate change will affect global food production and for informing policy decisions that aim to mitigate its negative effects.

Methodology

The goal of this study is to examine the impact of climate change on agricultural yields by examining how temperature, precipitation, and extreme weather events affect crop productivity. Building on the work of Lobell, Schlenker, and Costa-Roberts, who studied climate trends and their effects on crops such as maize, wheat, rice, and soybeans from 1980 to 2008, I will investigate how regional differences, extreme weather events, and temperature-precipitation interactions affect crop yields. I intend to examine locations with different climates to better understand how temperature changes affect agricultural productivity around the world.

In addition to temperature, extreme weather events like droughts and floods are expected to have a considerable impact on crop output. While gradual climate changes, such as rising temperatures, might affect productivity, extreme occurrences can cause more immediate and severe agricultural loss. I'll examine how such disasters impair agricultural production by using case studies such as Australian droughts and Russian heatwaves. Furthermore, I will study whether variations in precipitation have a greater impact than temperature on crop yields, as fluctuations in rainfall patterns, such as droughts or floods, might be just as important to crop performance.

By analyzing historical data on crop output and climatic patterns, I hope to uncover long-term fluctuations in agricultural yields in response to climate change. This research will contribute to a better understanding of how climate change affects global food production and what farmers and politicians can do to alleviate its effects on agriculture.

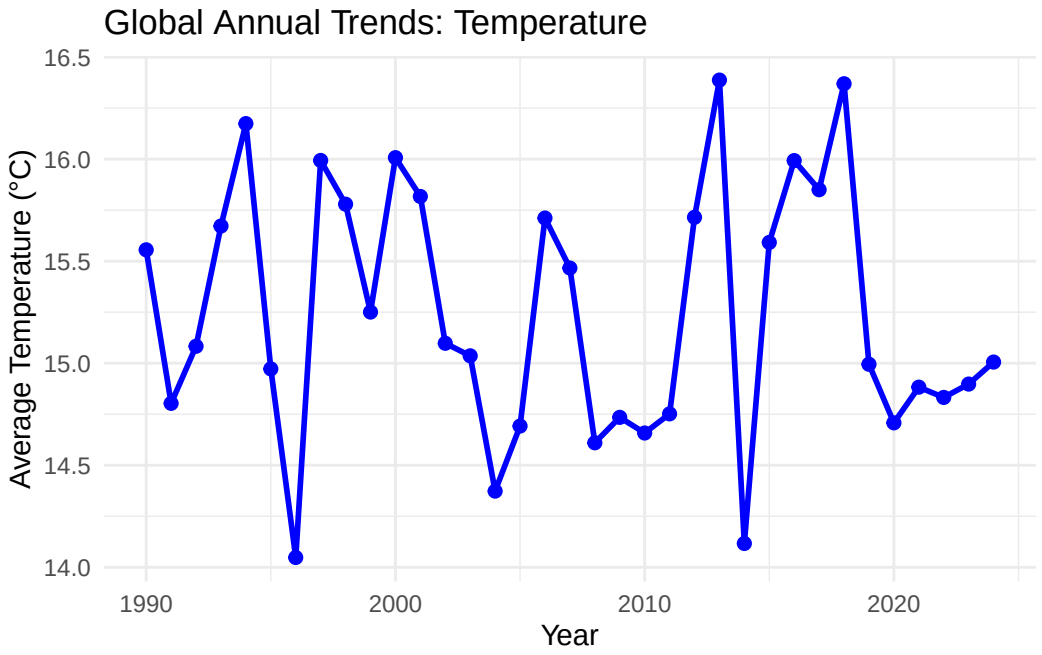
Data Exploration

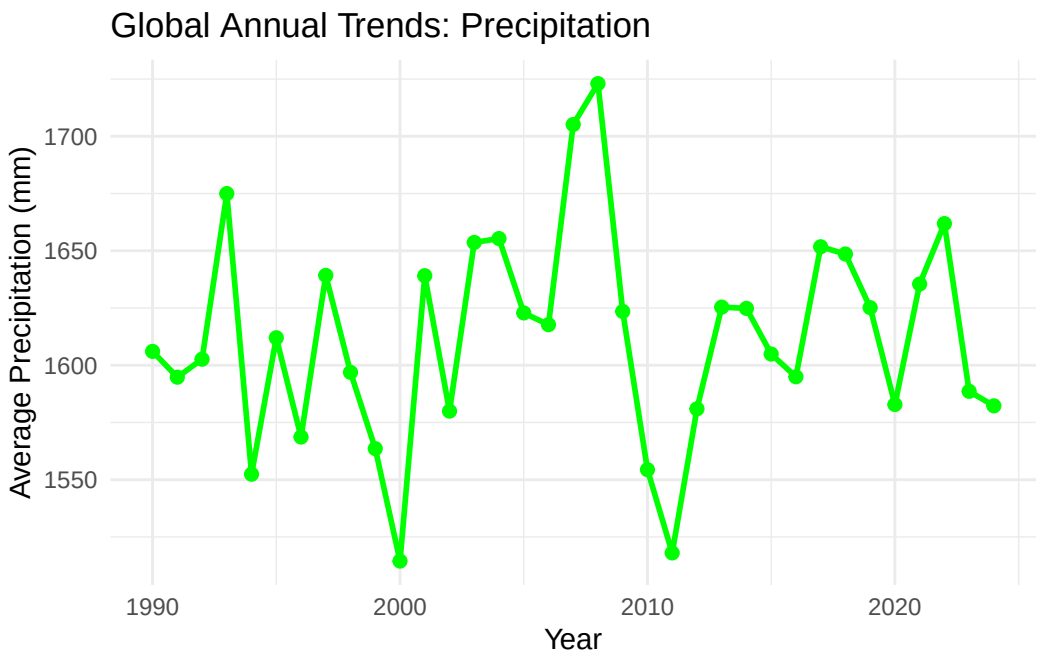
In this section, we dive into the trends linking temperature, precipitation, and crop yields over time. Our visualizations paint a clear picture: global temperatures are steadily climbing, rainfall patterns are becoming less predictable, and crop yields are fluctuating in response. These figures aren't just numbers—they tell the story of how agriculture is being shaped by a changing climate.

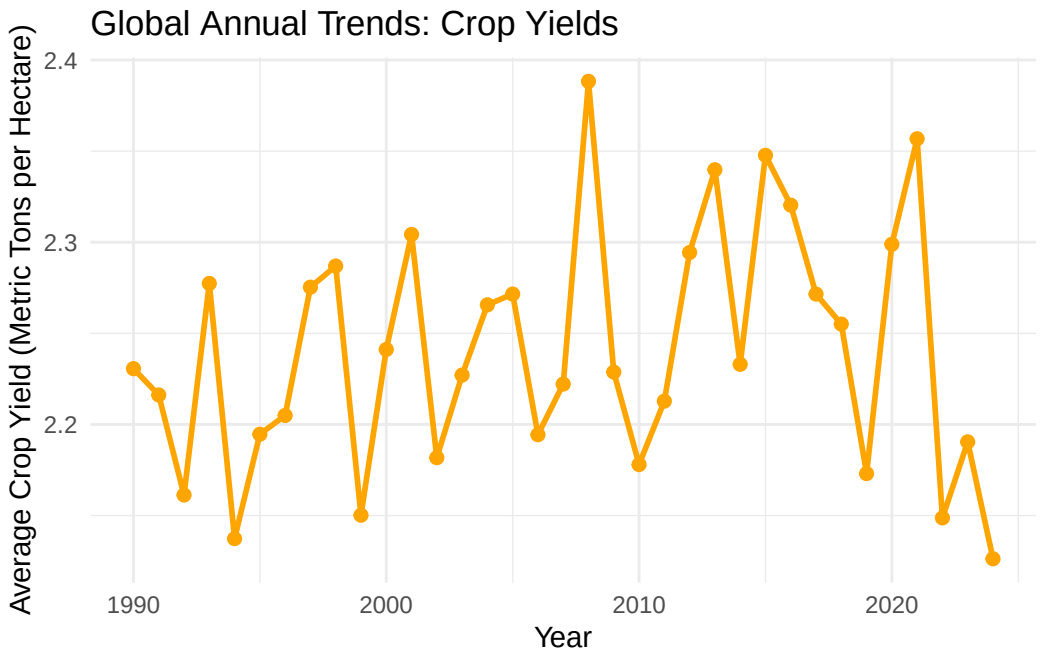
The temperature plot highlights the consistent warming trend, while the precipitation plot shows how rainfall varies from year to year. The crop yield trend ties it all together, revealing how these climate changes may be influencing agricultural productivity. These visuals make it easier to spot the connections: Are rising temperatures causing stress on crops? Could changes in rainfall be driving these ups and downs?

By breaking it down through these figures, we're better equipped to explore how climate change affects agriculture globally and to think about what these patterns mean for farmers on the ground.

The three figures below display the annual trends for global average temperature, total precipitation, and crop yields, providing a clear visualization of how these variables have changed over time.




Global Annual Trends: Precipitation
Average Precipitation (mm)
1700
1650
1600
1550
1990
2000
2010
2020
Year


Global Annual Trends: Crop Yields
Average Crop Yield (Metric Tons per Hectare)
2.4
2.3
2.2
1990
2000
2010
2020
Year

Results

Assumptions

Discussion