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# A Review of the Impact of Extreme Weather on Agricultural Economics

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## ABSTRACT

This paper reviews the changes in weather extremes, the characteristics of their economic impact on agricultural yields and commonly used quantitative analysis methods. With global warming, the frequency and intensity of extreme weather such as extreme heat, drought, and rainfall has increased. Extreme dry heat mainly affects the growth cycle, flowering, and pollination stages of crops; and extreme precipitation mainly affects the oxygen supply to the root system of crops. Extreme events lead to volatility in food market prices through a variety of mechanisms, such as affecting agricultural production, altering the balance between supply and demand, triggering changes in market expectations and speculative behavior, and prompting government policy responses. Extreme weather events are considered external shocks and are incorporated into various economic models to quantitatively assess their economic impact. The models still suffer from uncertainty in model parameters due to data related to extreme weather and market prices.

## KEYWORDS

Extreme Weather; Agricultural Yields; Economic Modeling.

## 1. INTRODUCTION

The frequency and intensity of extreme weather have increased significantly with global warming[1]. Extreme weather events have a direct impact on the ecological environment on which human beings depend for their livelihoods, and most of them have adverse impacts, seriously hindering sustainable socio-economic development[2]. Climate change, especially extreme weather and its impacts, has become a hot issue for governments and international organizations. *The Economics of Climate Change: The Stern Review*, published by renowned British economist Sir Nicholas Stern, assesses the impacts of climate change on the global economy, with a particular focus on the impacts of climate change and extreme weather on the global and regional agricultural economy, and concludes that developing countries, especially those dependent on agriculture, are likely to suffer more severe negative impacts and food security[3]. Understanding the impacts of extreme weather on the agricultural economy can help agricultural producers, policy makers and relevant stakeholders to better develop adaptation measures and strategies to address food issues.

## 2. CHARACTERISTICS OF EXTREME WEATHER AND ITS IMPACT ON AGRICULTURAL

The Intergovernmental Panel on Climate Change (IPCC) reports that the increase in the mean of the temperature means that hot days, hot nights, and heat waves have become more frequent; while cold days, cold nights, and frosts have become rare[2]. The higher temperatures have accelerated evapotranspiration processes, with droughts of greater intensity and duration being observed, especially in the tropics and sub-tropics. Furthermore, temperatures have increased, enhancing the atmosphere's capacity to hold moisture, which has led to a rise in the heavy rainfall. With the climate events of global warming and catastrophic weather occurring frequently, agricultural yields and the agricultural economy have shown dramatic changes. This section begins with a review of the characteristics of major extreme weather occurrences and their impacts on agricultural yields.

### 2.1. Impact of Extreme Dry Heat on Agricultural Yields

Extreme heat and drought usually go hand in hand as compound extreme weather events due to increased temperatures exacerbating evapotranspiration processes. Li demonstrated that compound dry and hot extremes have the greatest impact on the yield of rainfed maize by studying the influence of these extreme hot-dry events on maize production[4].

The influence of extreme heat and dryness on agriculture is primarily reflected in their impact on the growth cycle, flowering and pollination stages of crops, specifically extreme heat accelerating the growth cycle of crops, leading to premature ripening, resulting in a reduction in grain weight and yield. For example, staple crops such as corn, wheat and rice often experience yield reductions at high temperatures. High temperatures can affect the flowering and pollination processes of crops, reducing their fruiting rates. In particular, temperature-sensitive crops, such as wheat and soybeans, experience high temperatures during the critical flowering period that can lead to severe yield reductions. For instance, the unusually high temperatures during the winter and spring of 2015 resulted in crop indemnities exceeding $240 million for almond, cherry, grape, pistachio, peach, and walnut growers in California[5]. These problems often require the development and promotion of heat-tolerant varieties to improve crop yields and stability in hot conditions.

### 2.2. Impact of Extreme Precipitation on Agricultural Yields

Compared to extreme heat, the spatial distribution of extreme precipitation is characterized by a distinct latitudinal distribution with significant seasonal differences, especially in the monsoon region. It has been shown that the localization of extreme precipitation is increasing, while the persistence of precipitation is weakening, i.e., long-term heavy precipitation events are decreasing[6,7].

Extreme precipitation events often lead to significant crop losses and other flood-related damage[8]. Specifically, extreme precipitation affects the oxygen supply to plant roots, even leading to crop root rot; for soils, it can trigger soil erosion, leading to loss of soil nutrients and reducing land productivity. Droughts, on the other hand, may lead to soil salinization and exacerbate land degradation; in addition, extreme precipitation conditions make crops more susceptible to pests and diseases, which in turn affects yields. For example, high humidity environments favor the growth of fungi and molds[9-. It is evident that extreme precipitation usually affects agricultural yields by influencing crop growth, soil quality and pests and diseases. In the face of such disasters, the promotion of flood-resistant crop varieties, the strengthening of farmland water conservancy infrastructure, and the enhancement of flood and drought resistance are the main countermeasures.

### 2.3. Impact of Extreme Weather on The Agricultural Economy

Crop production reductions due to extreme events can have a knock-on effect on the global economy, starting with the demand side of the equation, where food, as a basic necessity, is relatively rigid in its demand; and even if prices rise, the reduction in demand is limited, which makes prices more sensitive to changes in supply. In response to such an impact, market expectations and speculative behavior that future supply may be unstable, pushing food prices up in advance. In the face of rising food prices, governments may intervene with measures such as price controls, subsidies or export restrictions. These policies may stabilize prices in the short term, but may distort market signals in the long term. In the context of economic globalization, high temperatures affecting food production and prices in a particular region may be transmitted to the global market through international trade, particularly affecting import-dependent countries. In 2010, extreme heat in Russia led to a reduction in wheat production. The Russian government subsequently banned wheat exports, which led to a significant increase in global wheat prices, affecting a number of countries dependent on Russian wheat imports. In 2012, the midwest region of the United States experienced extreme heat and drought, which led to a reduction in corn production. As the world's leading corn exporter, the reduction in U.S. production triggered a rapid rise in global corn prices.

Extreme events lead to price volatility in food markets through a variety of mechanisms, including affecting agricultural production, altering the balance between supply and demand, triggering changes in market expectations and speculative behavior, and prompting government policy responses. Comprehending these mechanisms can aid in devising effective policies and management measures to alleviate the adverse effects of extreme events on food markets and guarantee food security.

## 3. METHODOLOGY

In recent years, with the increased cross-fertilization of various disciplines, research outcomes concerning the quantitative analysis of the economic influence of weather and climate, utilizing economic methods and models, have been emerging[11]. proposed to introduce the concepts and methods of social sciences into meteorological sciences, and established a framework for research in the interdisciplinary field of weather and socio-economics, and implemented a research program on weather and socio-economic integration, WAS*IS (Weather and Society Integrated Studies).

Currently, the majority of studies have focused on analyzing the effects of extreme weather events on economic activities. These studies involve constructing extreme weather-economic models grounded in economic theories and integrating factors such as hurricanes, floods, droughts, high temperatures, and other extreme weather phenomena. These models combine climate science, economics, and statistics to evaluate the effects of extreme weather events on production, consumption, investment, and social welfare, and to help develop coping strategies.

### 3.1. Dynamic Stochastic General Equilibrium (DSGE) Models

The DSGE model is based on microeconomic theory and describes the interactions between firms, households, government and the external sector in an economy. The impact of stochastic shocks (e.g., extreme weather events) on the economy is considered. These models are employed to evaluate both the immediate and prolonged effects of extreme weather events on macroeconomic metrics like GDP, employment rates, and inflation levels.

In DSGE modeling, extreme weather events can be viewed as an external shock that affects multiple aspects of the economy. The main shocks include: 1) Production shocks, where extreme weather events, including floods, droughts, and high temperatures, directly impact the productive capacity of agriculture and other climate-dependent industries, causing a decrease in output. 2) Capital losses: extreme weather causes infrastructure damage, equipment damage, etc., leading to a reduction in the capital stock. 3) Labor shocks: extreme weather may cause workers to lose their jobs, relocate, or die, affecting labor supply. 4) Demand shocks: extreme weather changes the behavior of consumers and firms, leading to fluctuations in consumption and investment demand. To integrate extreme weather events into the model, one can define a shock function that characterizes their influence on the production function and other economic variables. Using historical economic data and extreme weather data, the model parameters are estimated by statistical methods. Simulation can yield dynamic responses of economic variables (e.g., GDP, consumption, investment, employment, etc.) post-extreme weather events. Analyzing these responses aids in comprehending the short- and long-term influence of extreme weather on the economy[13-15].

### 3.2. Computational General Equilibrium (GEM) Models

GEM model is an economic tool used to analyze the interactions between different markets and sectors in an economy. The model is usually framed in terms of consumers, producers and markets. Extreme weather variables are usually introduced into the production function of agriculture and related sectors to simulate the impact of extreme weather on yields. Additionally, the effects of extreme weather on natural resources, such as water resources and land quality, are taken into account, and the corresponding resource constraints are adjusted accordingly. There are also studies that introduce the probability distribution of weather events to consider the randomness and uncertainty of extreme weather events.

Several studies have developed GEMs to understand more generally the relevance of extreme weather events, climate change, on many sectors, and areas simultaneously[16-19]. The primary limitation of general modeling lies in the challenge of gathering data on market prices, potentially impacting the model's accuracy. Furthermore, many studies have employed geographic information systems (GIS) or satellite estimation to identify affected areas and evaluate the consequences of natural disasters[19-21]. GIS offers a viable solution for integrating spatial complexity into climate change and adaptation analyses[19].

### 3.3. Ricardian Model

GEM and DSGE models are typically employed to analyze entire markets, whereas the Ricardian model is often used to evaluate the effects of extreme weather events and climate change on specific markets[19]. The Ricardian model, rooted in David Ricardo's theory of comparative advantage, evaluates how climate change and extreme weather events influence agricultural productivity and economic outcomes. It accomplishes this by examining how varying climatic conditions affect land productivity and financial returns in agriculture, offering insights into the sector's resilience to climate variations.

When using the Ricardian method to analyze cross-sectional data for different years, there may be instability in the results. This instability can stem from various factors such as changes in weather patterns, shifts in agricultural practices, technological advancements, and fluctuations in economic conditions. To address this issue, researchers often employ techniques like panel data analysis or time series analysis. These methods allow for examining changes over time while controlling for other variables. Panel data, in particular, is valuable as it combines cross-sectional and time series data, providing more robust insights into the long-term impacts of climate change on agriculture[19]. To address this limitation, recent studies have calibrated Ricardian models using time series data rather than cross-sectional data[19-23]. Thus, analysis of different climate periods can provide a more accurate measure of the climate change problem. Two time-series data methods commonly used in the Ricardian model are the Hsiao two-stage model and the "pooled" data model[19,24].

## 4. SUMMARY AND OUTLOOK

This paper reviews the changes in extreme weather, the characteristics of the economic impact on agricultural production and the commonly used methods of quantitative analysis. There are several summaries for the study of the economic impact of extreme weather on agriculture as follows:

There are still many uncertainties in the assessment of the impact of extreme weather on agriculture. It is limited by the lack of understanding of the combined effects of extreme weather processes on crops. There is a need for more observational and simulation studies on the influence of environmental changes on crop yield and quality: to study the influence of extreme weather on the growth and development process, photosynthetic physiological and ecological processes, yield and quality of major crops and their control mechanisms; and to reveal the impact and mechanisms of high temperatures, cold damage, drought, waterlogging and other agro-meteorological disasters on crop yield and quality.

When using extreme weather-agricultural models to study the influence of extreme weather on agricultural economics, the assumptions in the models are mostly based on previous studies and are not necessarily applicable to different regions, crops and disasters due to insufficient economic data. Using modeling tools to carry out quantitative research, there is bound to be a certain degree of uncertainty in the results of the study, from the construction of the model to the selection of parameter estimation methods need to be further explored to promote the development of the cross-cutting research field of meteorology and economics.

Assessing the socio-economic impact of weather forecasts and climate prediction information is a research direction that needs to be strengthened in China now and in the future. In terms of mitigating the adverse impacts of abnormal weather, with the continuous improvement and maturity of the market economy, weather insurance and weather derivatives are also bound to be further developed in China as an important means of mitigating the adverse influence of extreme weather and climate events.

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