A Vicious Cycle Between Agriculture Supply Chain and Climate Change

Xinggang Guo*

Rutgers Business School, New Brunswick, the United States

* Corresponding Author Email: xg153@scarletmail.rutgers.edu

Abstract. Agricultural production and climate have an interdependent and mutually influential relationship. Contemporarily, agricultural development and the environment have reached a dilemma — providing more agricultural products for a growing population while decreasing hazardous gas emissions in the whole agriculture supply chain. A comprehensive analysis of the current research results that focus on contradictions between agricultural production and climate change is the central concern of this thesis. Several studies have explained climatic influences on agricultural products' nutrition, quantity, and sustainability. And types of existing research papers explained how modern agricultural supply chains contribute to climate change. Current studies studying agricultural supply chains and climate change mainly use linear regressions with historical data from different countries and projections of future data. There are also some articles based on historical data demonstrating the main factors influenced by the environment in each part of the entire supply chain flow chart through a logical flow. This article focuses on analyzing the limitations of current research on climate change and the agriculture supply chain and developing potential future research directions to guide current research in this field. The significance of this article is the expanding consciousness of the side-effects of growing agricultural products' yields and the urgency to consider climate change as a crucial fact to food security based on analyzing existing papers.

Keywords: Agriculture; Supply chain; Climate change; greenhouse gas emissions.

1. Introduction

In the summer of 2022, the United Kingdom, which has a temperate maritime climate, monitored the first high temperatures above 40 degrees Celsius in recent decades. Meanwhile, droughts and wildfires spread in other European countries under a high-temperature thermal wave. According to the World Agricultural Production Report, the U.S. Department of Agriculture's Foreign Agricultural Service (FAS) reports that the European Union's (MY) 2022/23 corn production forecast will be fifteen percent lower than the same period last year, which is ten percent lower than the average annual yield five years ago, with the main reason for the yield decline being drought caused by extreme unpredictable heat during the crop's pollination period [1]. Greenhouse gas emissions, whose largest emitting sectors are agriculture, forestry, and other land use changes, significantly contribute to climate anomalies. In the anthropogenic greenhouse gas part, 11% comes directly from agricultural production, such as methane from the digestion of cattle and nitrous oxide from fertilizer, and 12% from land use change, such as deforestation [2]. Extreme climate, such as high temperature, decreases agriculture production which will also accelerate climate change. Subsequently, there is a vicious cycle between agriculture and climate change.

The world population will reach its maximum (around 10 billion people) by 2050. The increasing world population will boost the need for farming products [3]. The United Nations Food and Agriculture Organization claims that the global communities' demand for agricultural products and livestock will increase by seventy percent in 2050. To meet this enormous demand, the whole agricultural supply chain, especially for the production parts, needs to become as efficient as possible [4]. To improve agricultural production efficiency, farmers tend to abuse chemical inputs, such as nitrogen and phosphorus fertilizers, which decline the water table and quality of underground water [5]. Besides the overuse of fertilizers, the entire agriculture supply chain, from production to food commodities, emits significant amounts of CO_2, which causes agriculture to become one of the most potent contributors to climate change in anthropogenic activities [6]. The impact of agricultural supply chains and climate change is bidirectional. With agricultural supply chains accelerating climate change, climate change also worsens agricultural supply chains. For agriculture production, the hydrological cycle is critically affected by climate change through changing precipitation, which will decrease agricultural yields due to floods or droughts [7]. Increased extreme weather frequency due to climate change has also seriously impacted agriculture transportation. Specifically, extreme weather conditions damage existing infrastructure and slow food shipments, increasing the risk of food damage or spoilage during transportation. Increased extreme weather frequency due to climate change has also seriously impacted agriculture transportation. Specifically, extreme weather conditions damage existing infrastructure and slow food shipments, increasing the risk of food damage or spoilage during transport [8]. The stable supply of agricultural products is of great relevance to end consumers, and climate change will affect the access of end consumers to adequate food by increasing the instability of food supply channels. An inadequate food supply in a country will dramatically increase the number of malnourished famine refugees. [9].

The motivation of this paper is the abnormally high temperatures in the northern hemisphere will cause severe impacts on agriculture in 2022. In the United States of us, the high temperature killed at least 2000 heads of cattle in Kansas alone. Climate change and agricultural supply chains are negatively impacting each other. This article is to help the reader better understand the vicious cycle between them. The paper is separated into five different aspects. The first part introduces the background of the paper. Then the literature review is covered with a solid scientific basis and major research theories. Section 2 and section 3 analyze methodologies and the result. And section 4 explains the limitation and future outlooks of existing research. Finally, the investigation's conclusions will be exhibited at the end of the paper.

2. Methodology

The two main methods of studying climate change and agricultural supply chains are line charts and linear regression models. A line chart clearly illustrates the evolution of a set of statistics throughout a sequential time interval or period. It features the most straightforward and concise way to reflect the movement of events over time. Within the line graph, it is obvious to observe the characteristics of changing or trend of data, the rate, and the patterns such as periodic. Therefore, Line graphs are one of the best ways to diagnose historical data shifts as a function of time, and can also be used to examine the relationships and changes between multiple sets of data shifts under temporally altered conditions. The decline in the line graph of the agriculture-to-GDP ratio in developing countries for the past few years has meant that food prices have less affected food security [9]. Based on historical and estimated data, wheat yields are affected by CO2 concentration in both developing and developed countries [10]. From 1960 to 2010, even though agricultural technology improved crop yields, climate extremes seriously affected crop yields. From the line graph, we can obviously notice that each drought or flood causes a sharp decrease in yield [11]. The line chart can directly show the trend and range of the data, reflecting the variation for analysis, but it cannot show the total percentage of the data.

In contrast to line graphs, which focus on historical statistical data, linear regression models play an essential role in predicting climate change and future trends in agricultural supply chains. Linear regression can be used in forecasting models to identify the relationship between the independent and dependent variables quickly and to forecast future trends from historical data. The p-value can judge the credibility of the model. A p-value less than 0.05 indicates that the coefficient of the relationship between the independent and dependent variables is significant, so it can effectively prove that there is a correlation between the selected independent and dependent variables. Conversely, a p-value greater than 0.05 indicates that the coefficient of the relationship between the independent and dependent variables for the selected data is not valid, indicating that the selected independent and dependent variables are not significantly correlated. When new data is generated in linear models, it is easy to update the model without parameter tuning and feature scaling. Linear regression models are essential for the relationship between agricultural yields and variables, such as greenhouse gas methane emissions [12]. However, linear regression models are not applicable to non-linear data, have low prediction accuracy, may be over-fitted, and do not represent an insight into the interaction of features in the dataset.

3. Climate Change Impacts on the Agricultural Supply Chain

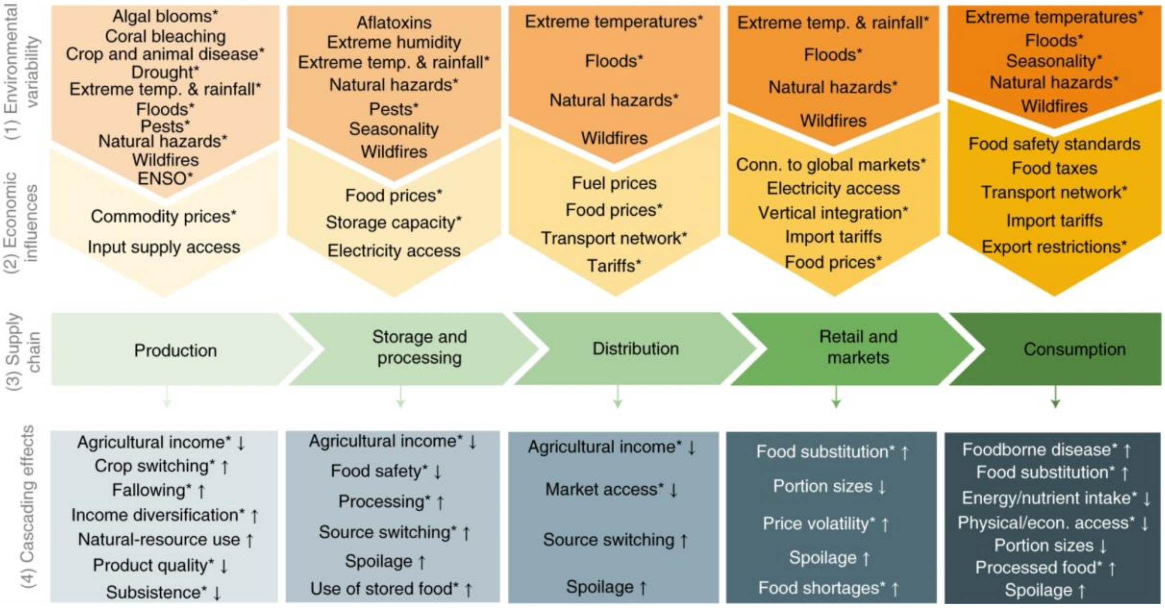

Figure. 1 Every stage for climatic mutability in the agricultural supply chains.[8]

In this model, the researcher divided the relationship between climatic mutability and the agricultural supply chain vertically into four levels, (1) environmental variability (2) economic influences (3) supply chain (4) cascading effects, and horizontally into five departments, production, storage and processing, distribution, retail and markets, and consumption. This is a chain reaction from top to bottom from left to right.

Storage is the most crucial part of the agricultural supply chain because individuals pursue fresh and healthy food as the economy grows and health-conscious populates. Precipitation and temperature are unstable under the influence of climate change. Keeping the temperature and humidity in the warehouse stable is challenging, which can easily cause waterborne disease and food spoilage in warehouses [8]. Even in drier regions, increasing precipitation and higher temperature also affect food storage. The reason is that higher temperatures and rising moisture provide an excellent opportunity for pests to survive. The life cycle of pests will become longer and more numerous, making it more challenging to keep food in safe areas [9].

From the transportation part, unstable precipitation affects the agricultural supply chain by alerting the glow and velocity of rivers. Excessive rainfall causes the rivers to flow too fast, making it easy for food-carrying ships to lose their cargo due to the swaying of the vessel during transportation. Conversely, insufficient precipitation reduces the flow of the river. It prevents the standard passage of cargo ships, leading to delays in food transport and increasing the risk of food damage or spoiling during transport.

For the end consumers, the most critical issue affecting them is the security and nutrition of food. Total global food declines, but the population continues to grow under the impact of climate change, leading to 30% of farmers in developing countries being food insecure [13]. Even if people can buy enough food in developed countries, the nutrition of the food will be influenced by climate change. Specifically, increasing variations in rainfall are associated with changes in the level of fatty acids in the bodies of certain species of fish and a decrease in protein from milk [14].

4. Agriculture Impacts on Climate Change

Increasing the level of climate change will decrease agricultural yields. The relationship between them is negative [15]. In another article, researchers using regression models between setting the net agricultural production value as a dependent variable and setting the level of total greenhouse gas emissions, the level of methane emissions, and the level of CO2 emissions as independent variables separately prove that there are positive trends between them.

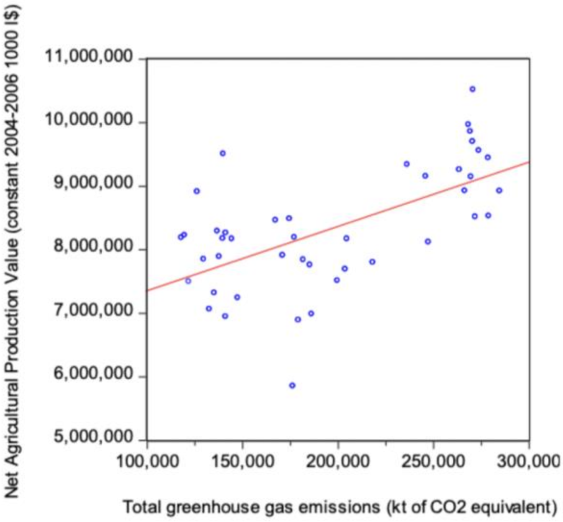

Fig. 2 The relationship between the aggregated greenhouse gas emissions and net agricultural production value [12]

In Fig.2, the diagram shows that as the net agricultural production value increases by 1 unit, the total greenhouse gas emissions will also rise by 0.603 units under a standard error of 0.007. F-statistics is 0.000019 showing that it is a valid model [12]. The primary greenhouse gas emissions come from machines' operation during land-using changes, such as deforestation and chemical fertilizers [15].

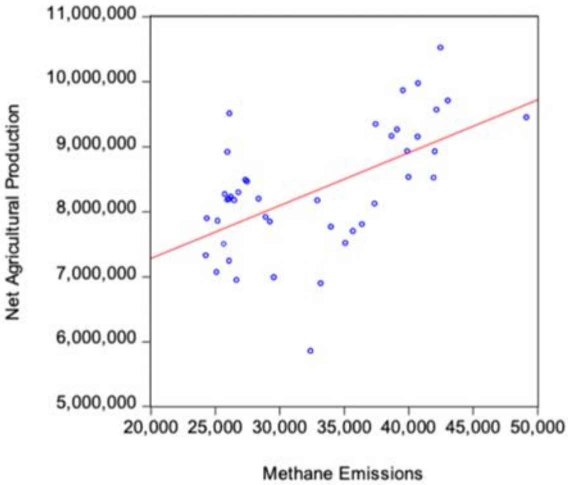

Fig. 3 The relationship between aggregated methane emissions and the net agricultural production value [12]

In Fig.3, the graph shows that as the Net Agricultural Production value increases by 1 unit, the methane emissions will also rise by 0.580 units under a standard error of 0.001. F-statistics is 0.000045, proving that it is a valid model. The primary sources of methane emissions are methane production by ruminant animals and dejection from grazing animals [12].

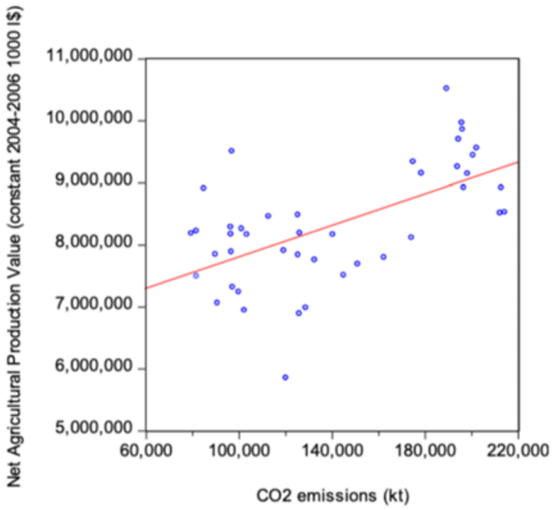

Fig. 4 The relationship between aggregated Carbon Dioxide emissions and the net agricultural production value [12]

In Fig.4, the graph shows that as the net agricultural production value increases by 1 unit, CO2 will also rise by 0.580 units under a standard error of 0.006. F-statistics is 0.00029, proving that it is a valid model.

Although the authors derived a positive linear relationship between crop yields and total greenhouse gas, CO2 and methane emissions by means of linear regression, the authors did not take into account the endogenous issue. In endogenous problems, what is shown to be related to the data may be caused by a third party. Specifically, the increment in total greenhouse gas emissions is potentially the result of increased vehicle emissions associated with a larger population, the enhancement of methane emissions probable caused by increased methane emissions from wetlands under warming conditions, and the increase in total CO2 emitted volume possible driven by an increase in total industrial emissions and fuel usage.

5. Limitations & Future outlooks

It is critical to be aware that all the current academic studies and assessments of the world food supply situation focus simply on the implications of the average climatic variability on food supply, even in the context of food availability. That is most researchers do not take into account the potential for significant changes to the intensity of extreme climatic events on regional production potential, nor do they consider unexpected climate change situations or any of these situations changes that could augment the anticipated adverse expected influences of impacts of the global farming product supply due to the climatic shifted phenomenon. The present study has not considered the impact of simulations on these scenarios. Also, the relationship between different crop yields and growth conditions, such as CO2 concentration or temperature, is not detailed. The possibility of higher crop yields with higher CO2 concentration at higher temperatures cannot be excluded. Finally, the experiment could not disentangle the impact of the agricultural supply chain on the environment due to differences in people's income, per capita food supply, employment opportunities, population growth rates, urbanization levels, and per capita arable land between countries.

Current research on climate change and agricultural supply chains has focused on analyzing the effects of different climatic environments, such as CO2 concentration and temperature changes on crops, and how agricultural supply chains affect climate change from production to consumption. Future research could take an economic perspective to understand the intensity of adaptation in agriculture and examine the extent to which agriculture can adapt to climate change and its associated shocks. One is to compare the different feedbacks of the same crop to varying temperatures in the immediate and extended term, and the difference between them is a reflection of adaptation. The other is to use microeconomics to analyze how different behavioral feedbacks respond to changes in temperature and precipitation. Future implications study of crops on climate could focus on the research on the concentration of greenhouse gases produced by different organic fertilizers in the production of various crops, the development of genetically modified healthy crops that are less harmful to the environment in the farming process, and the improvement of an environmentally friendly agricultural supply chain.

6. Conclusion

The paper first describes the strengths and weaknesses of the core methods used in the field of agricultural supply chains and climate change, folding statistics, and linear regression. It then analyzes the impact of environmental change on each sector of the supply chain in an agricultural supply chain flowchart. Then the positive relationship between agricultural yields and climate change are analyzed by linear regression. Finally, the limitations and future prospects of the field are presented. The article explains the vicious cycle between the agricultural supply chain and climate change by analyzing the impact of each stage of the agricultural supply chain flow chart on climatic modification and by analyzing the influences of greenhouse gases on crop capacity through line graphs. This paper aims to make more scholars aware that finding a balance between the agricultural supply chain and climate change is an urgent and challenging issue in the face of increasing food demands. The existing central studies focus on analyzing the impact of climate change on food security and crop yields and the impact of greenhouse gases emitted during the production of different agricultural products on climate change. However, little research has been done on other links in the agricultural supply chain. Under the condition that a healthy diet is becoming popular, and efficient green agricultural supply chain should be the focus of both businessmen' and scholars' relationships. Secondly, there is a lack of research on the adaptation of agricultural products to climatic variability and the climatic variability shocks on the acreage of different crops. Currently, changes in crop acreage are thought to come mainly from the impact of prices, agricultural policies, and technological advances. Still, few studies have mentioned the adaptation of crops to climatic alterations and the influences of climatic shocks on crop acreage. By examining these three topics, future research can contribute to the balance between agricultural supply chains and climate change.

References

[1] Cheng Qiyun, Sun Caixin, Zhang Xiaoxing, et al. Short-Term load forecasting model and method for power system based on complementation of neural network and fuzzy logic. Transactions of China Electrotechnical Society, 2004, 19(10): 53-58. [1] “Crop Explorer for Major Crop Regions - United States Department of Agriculture.” International Production Assessment Division (IPAD) - Home Page, https://ipad.fas.usda.gov/cropexplorer/pecad_stories.aspx?regionid=europe&ftype=prodbriefs.

[2] “Climate Change and Agricultural Production: An Overview of Risks and Opportunities.” Ceres, https://www.ceres.org/resources/reports/climate-change-and-agricultural-production-overview-risks-and-opportunities.

[3] Fess TL, Kotcon JB, Benedito VA. Crop Breeding for Low Input Agriculture: A Sustainable Response to Feed a Growing World Population. Sustainability. 2011; 3(10):1742-1772.

[4] “2050: A Third More Mouths to Feed.” FAO, Food and Agriculture Organization of United Nations, https://www.fao.org/news/story/en/item/35571/icode/.

[5] Jat1, L. K., 1Department of Soil Science and Agricultural Chemistry, Agronomy, 2D. of, & Agriculture, 3I. C. A. R.-V. I. of H. (2020, August 6). Does integrated nutrient management, enhance agricultural productivity? Journal of Pure and Applied Microbiology. Retrieved September 29, 2022, from https://microbiologyjournal.org/does-integrated-nutrient-management-enhance-agricultural-productivity/

[6] Campbell BM, Beare DJ, Bennett EM, et al. Agriculture production as a major driver of the Earth system exceeding planetary boundaries. Ecology and society: a journal of integrative science for resilience and sustainability. 2017;22(4).

[7] Kumar, M. Impact of climate change on crop yield and role of model for achieving food security. Environ Monit Assess 188, 465 (2016). https://doi-org.proxy.libraries.rutgers.edu/10.1007/s10661-016-5472-3

[8] Davis, K. F., Downs, S., & Gephart, J. A. (2021). Towards food supply chain resilience to environmental shocks. Nature Food, 2(1), 54-65. https://doi.org/10.1038/s43016-020-00196-3

[9] Josef Schmidhuber, Francesco N. Tubiello. Global food security under climate change. 2007; 104 (50) 19703-19708.

[10] Praveen, B., & Sharma, P. (2019). Climate change and its impacts on Indian agriculture: An econometric analysis. Journal of Public Affairs, 20(1).

[11] US EPA. Climate Impacts on Agriculture and Food Supply | Climate Change Impacts | US EPA. (n.d.). Retrieved September 29, 2022, from https://climatechange.chicago.gov/climate-impacts/climate-impacts-agriculture-and-food-supply

[12] Nicolae Istudor & Raluca Andreea Ion & Irina Elena Petrescu & Andrei Hrebenciuc, 2019. "Agriculture and the Twofold Relationship between Food Security and Climate Change. Evidence from Romania," The AMFITEATRU ECONOMIC journal, Academy of Economic Studies - Bucharest, Romania, vol. 21(51), pages 285-285.

[13] Brown ME, Funk CC. Climate. Food security under climate change. Science. 2008 Feb 1;319(5863):580-1. doi: 10.1126/science.1154102. PMID: 18239116.

[14] Gephart, J. A., Deutsch, L., Pace, M. L., Troell, M. & Seekell, D. A. Shocks to fish production: identification, trends, and consequences. Glob. Environ. Change 42, 24–32 (2017).

[15] Massimiliano Agovino, Mariaconcetta Casaccia, Mariateresa Ciommi, Maria Ferrara, and Katia Marchesano. "Agriculture, climate change and sustainability: The case of EU-28" Ecological indicators 105, (2019): 525-543.