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Food security, agricultural investment, and climate change: A global empirical analysis

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ABSTRACT

The conditions of world hunger are centered on countries on the African continent and a small part of the Asian continent. This condition highlights the inequality of hunger conditions globally. The situation is exacerbated by rising food prices and the conflict between Ukraine and Russia, which has caused an increase in agricultural input prices. To address these challenges, agricultural investment is necessary. However, another factor threatening food security is climate change. Therefore, this study aims to analyze the influence of agricultural investment and climate change on food security, as proxied by food availability globally and based on continental groupings: Africa, Asia, Europe, Oceania, North America, and South America. This study uses data from 159 countries over the period 2002-2022, sourced from the World Bank and FAOSTAT, and processed using the panel regression method. Empirical results show that agricultural investment has a positive effect on food security. Climate change, with temperature indicators, has a negative effect on food security globally and on the Africa, Europe, and Oceania continents, but does not affect Asia, North America, and South America. Climate change, with rain indicators, has a negative effect on food security globally and on Africa, Asia, Europe, North America, and South America, but does not affect Oceania.

Contribution/Originality: This study contributes to the existing literature by analyzing agricultural investment and climate change on food security across continents. It uses a new estimation methodology with a rainfall decile index. It is one of the few studies that have investigated global food security with panel data. The primary contribution of the paper is finding that agricultural investment enhances food security but cannot offset rising temperatures.

1. INTRODUCTION

One of the priorities in the Sustainable Development Goals (SDGs) is "Zero Hunger," which aims to eradicate hunger, ensure food security, and improve community nutrition (United Nation, 2015). Strategies such as reducing food loss and waste are key in creating a balance between sustainability, resilience, and food security to address hunger (Vågsholm, Arzoomand, & Boqvist, 2020). FAO commemorates World Food Day every October 16th to raise global awareness about food security and hunger (Oyelami, Edewor, Folorunso, & Abasilim, 2023). According to Food and Agriculture Organization of the United Nations (FAO) (1996), food security is achieved when everyone always has physical and economic access to sufficient, safe, and nutritious food. This concept includes four main dimensions, namely food availability, accessibility, utilization, and stability.

The Economist Group (2022) recorded a downturn in global food security scores since 2019 due to the pandemic, armed conflict, and climate change. This condition is exacerbated by reliance on food aid, lack of infrastructure such as irrigation and transportation, and the Russia-Ukraine conflict, which accounts for major shares of global wheat, corn, and sunflower oil trade. In addition, the high cost of agricultural inputs worsened food availability (Ben Hassen & El Bilali, 2024; Rother et al., 2022). Conflict has reduced agricultural production through war, damage to water infrastructure, and disruption of input distribution (Filho et al., 2023). Rising energy prices have also increased the cost of fertilizers and pesticides, thereby affecting global food production and prices. These pressures are further compounded by the effects of the COVID-19 pandemic (Alexander et al., 2023; Stephens, Martin, Van Wijk, Timsina, & Snow, 2020). This problem reflects a disruption to the global food supply.

Global food disruption is a complex, interrelated phenomenon. One of its main drivers is climate change, which negatively affects food production systems and food security as a whole (Farooq et al., 2022). According to Fanzo, Davis, McLaren, and Choufani (2018), climate change is the main trigger of the global food crisis because of the close link between climate, agriculture, and food. Climate change is affecting temperatures, precipitation, and extreme weather events that are becoming more frequent and severe. This condition has led to a decline in crop yields, livestock productivity, and fishery and agroforestry products, especially in areas that are already vulnerable to food crises (FAO, IFAD, UNICEF, WFP, & WHO, 2017)

The Intergovernmental Panel on Climate Change (IPCC) (2014) stated that climate change has a negative impact on food crops, livestock, and fisheries, and threatens food security through the loss of livelihoods, marine and aquatic ecosystems, and the destruction of food systems. Climate variability and extreme events such as droughts reduce agricultural production and increase food insecurity, particularly for smallholder farmers (Kandel, Bavorova, Ullah, & Pradhan, 2024). These conditions also hinder household efforts to achieve food security (Brenya, Jiang, Sampene, & Zhu, 2024).

Farmers, fishers, and forest dwellers need government and private sector support to meet the challenges of climate change. Investment in the agricultural sector can encourage the development of environmentally friendly technologies and crop varieties that are resistant to extreme climates, thereby maintaining the stability of food production (Food and Agriculture Organization of the United Nations (FAO), 2021; Grigorieva, Livenets, & Stelmakh, 2023). Variety diversification enhances nutritional diversity and strengthens food security at local and global levels (Pawlak & Kołodziejczak, 2020). This demonstrates that agricultural investment influences the supply side of food security. Global agricultural investment, primarily originating from developed countries, exhibits an inclusive trend; however, its distribution is uneven, as food-insecure countries receive only 20% of the investment, with projects generally being small-scale (Zhao & Chen, 2023).

Global food security now faces structural challenges from climate change, which heightens uncertainty in food production, particularly in countries with chronic food insecurity (Intergovernmental Panel on Climate Change (IPCC), 2022). Although agricultural innovations have progressed, investment remains unevenly distributed. Developed countries dominate funding and technology flows, while developing countries lack sufficient financial and institutional support to adapt (Zhao & Chen, 2023). This inequality reinforces the cycle of vulnerability, where smallholder farmers in food-insecure areas struggle to access agricultural tools, practices, and infrastructure that are resilient to climate change (Mbuli, Fonjong, & Fletcher, 2021; Mutengwa, Mnkeni, & Kondwakwenda, 2023). Climate change has a negative impact on food production and food security, requiring investment in mitigation and adaptation measures (Farooq et al., 2022).

Global agricultural investment still focuses on production efficiency in established regions, rather than building resilience in vulnerable areas (Nyström et al., 2019). As a result, traditional and low-yielding approaches remain prevalent in developing countries, magnifying the risk of famine in extreme climatic conditions (Arreyndip, 2021). Based on this condition, how and to what extent can governments and non-governmental organizations address food insecurity affected by climate change through agricultural investment? This study analyzes food security, agricultural investment, and the climate crisis globally. We divided the analysis into six continents to capture the geographical and demographic differences of each region because, according to the Intergovernmental Panel on Climate Change (IPCC) (2007) each continent in the world has different climatic and demographic conditions.

This study proposes several research updates (more details are discussed in Part 2). The rest of the paper is structured as follows: Part 2 presents a literature review, and Part 3 provides a description of the model and data. Interpretation and discussion of the results are presented in Part 4. Finally, Section 5 offers conclusions and policy recommendations.

2. LITERATURE REVIEW

According to Food and Agriculture Organization of the United Nations (FAO) (1996), food security does not only depend on the availability of food sources but also involves various important aspects such as accessibility, utilization, and stability. Food and Agriculture Organization of the United Nations (FAO) (1996) defines food security as a condition in which everyone, at all times, has physical and economic access to sufficient, safe, and nutritious food to live an active and healthy life. Factors such as extreme weather, climate change, political instability, and economic conditions such as unemployment and rising food prices can significantly disrupt food security (Food and Agriculture Organization of the United Nations (FAO), 2015; Kemmerling, Schetter, & Wirkus, 2022).

Several studies that have been conducted using the variables of food security, agricultural investment, and the climate crisis show diversity in the use of data or indicators. To measure food security, previous research used various types of data, such as the Food Security Index (Gobezie & Boka, 2023; Lee, Zeng, & Luo, 2024), Agricultural GDP (Oyelami et al., 2023), agricultural gross fixed capital formation (Ceesay & Ndiaye, 2022), average food energy supply (Kamenya, Hendriks, Gandidzanwa, Ulimwengu, & Odjo, 2022), per capita food supply (Campi, Dueñas, & Fagiolo, 2021). Meanwhile, several food security studies are represented by food availability using the Food Production Index (Brenya et al., 2024; Mahrous, 2019) and cereal production (Oyelami et al., 2023).

Previous research on climate change has also involved a variety of data measurements to determine the extent of climate change. To measure climate change, previous studies use CO_2 emissions (Brenya et al., 2024), greenhouse gas emissions (Gobezie & Boka, 2023), average annual rainfall (Ceesay & Ndiaye, 2022), and average annual rainfall as well as average annual surface temperature (Mahrous, 2019; Oyelami et al., 2023), and adding the annual sunlight clock (Lee et al., 2024). Previous research on agricultural investment also involves a variety of data measurements. To measure agricultural investment, previous studies used public agricultural investment data (Kamenya et al., 2022) foreign direct investment in the agricultural sector (Doğan, 2022).

This research offers innovation in two main aspects. First, the measurement of the climate crisis uses rainfall indicators that are processed into the Decile Index and formed into dummy variables, thus allowing for a clearer analysis of the impact of extreme rainfall than the annual average rainfall. Second, agricultural investment using agricultural gross fixed capital formation data, which reflects overall investment in the sector, as opposed to the previous approach that only used public investment or FDI.

Empirical findings suggest that investment, particularly FDI and certain types of foreign aid, can reduce poverty and improve food security in developing countries by developing the agricultural sector (Dhahri & Omri, 2020). Other findings suggest that investment in agricultural infrastructure and counseling services, along with measures to increase household purchasing power, are key to improving food security in developing countries (Pawlak & Kołodziejczak, 2020). Amadu, McNamara, and Miller (2020) found that CSA aid investments in Malawi increased maize yields by 53%, demonstrating the potential to improve food security in the face of climate change.

On the other hand, Fusco (2022) found that climate change, as indicated by temperature, affects food security in North and East African countries. Mirón, Linares, and Díaz (2023) found that climate change negatively impacts food production and increases food security risks, although the impacts are complex and uneven across regions. In Malaysia, the impacts of climate change, including rising temperatures and rainfall, pose a serious threat to rice production and food security (Firdaus, Leong Tan, Rahmat, & Senevi Gunaratne, 2020). Climate change, with rising temperatures, negatively impacts agriculture and food security through its effects on plant physiology, pests, and soil microbes (Malhi, Kaur, & Kaushik, 2021). According to Rezvi et al. (2023) the impact of climate change, such as changes in rainfall, has a negative effect on crop production and food security.

Although previous studies have analyzed the linkages between agricultural investment, climate change, and food security, there are still a number of important gaps. First, most studies only use annual average rainfall indicators, so they are less able to capture the impact of climate extremes on food security. Second, the measurement of agricultural investment is generally limited to FDI or public investment, which does not fully reflect the total accumulated investment in the agricultural sector. Third, the existing research mostly focuses on specific countries or regions, so it does not reflect the variation across continents. The study fills the gap by using decile index-based rainfall indicators, gross fixed capital formation data for the agricultural sector, and analysis of a panel of 159 countries divided into six continental regions to provide a more comprehensive understanding.

3. METHOD

Based on the problems and objectives that have been formulated previously, the model of this research is as follows.

$$fs = f(AgriI, CC, Z) \qquad (1)$$

Where fs is food security, AgriI is agricultural investment, CC is the climate change, and Z is the control variable. This research focuses on food availability as a proxy for food security. Grigorieva et al. (2023) states that agricultural investment helps the development of agricultural technologies that are more environmentally friendly and can increase food varieties that are more resistant to the climate crisis. It can be concluded that investment affects the supply side of food security. Food security itself has four dimensions, namely food availability, food access, food utilization, and food stability. Of the four dimensions, what is included in the supply side is the availability of food. Therefore, we focus on the dimension of food availability.

The Intergovernmental Panel on Climate Change has observed climate change and has concluded that the climate crisis is affecting food security through increased temperatures, changes in rainfall patterns, and an increased frequency of some extreme events such as droughts and floods (Mbow et al., 2019). Therefore, this study uses temperature and rainfall as indicators in the climate crisis. Then the indicator is inserted into the model of Equation 1 so that it changes to the following.

$$FS = f(AI, Temp, Prec, Z) \qquad (2)$$

Where FS is food security that has been proxied with food availability, Temp is the average annual surface temperature, and Prec is precipitation. In contrast to some previous studies that used average annual rainfall data for the precipitation indicator, we adopted the precipitation decile index to determine the impact of abnormal rainfall on food security. The calculation of the precipitation decile index is carried out by sorting the data from highest to lowest to build a cumulative frequency distribution. The distribution is then divided into 10 parts (decile). The first decile is the rainfall value that is not exceeded by the bottom 10 percent of all precipitation values in a long-term rainfall record; the second is between the lowest 10 and 20 percent, and so on. Any rainfall value can be compared to and interpreted in these deciles. Referring to the research of Raziei and Pereira (2024), normal rainfall is between the 30 percent and 70 percent deciles are used as reference points. Subsequently, the value is employed as a dummy variable, where the rain dummy is assigned a value of 1 if the first year's rainfall data falls outside the normal decile range either exceeding 70 percent or falling below 30 percent; otherwise, it is assigned a value of 0. The control variable is then substituted, and the simple form of the model is modified accordingly.

$$FS_{i,t} = \alpha + \beta_1 AI_{i,t} + \beta_2 Temp_{i,t} + \beta_3 Prec_{i,t} + \beta_4 GDP_{i,t} + \beta_4 FI_{i,t} + \beta_5 GDPAgri_{i,t} + \beta_6 Labor_{i,t} + e_{i,t} \quad (3)$$

The control variables in this study are GDP Per Capita (GDP), Food Inflation (FI), Agricultural GDP (GDPAgri), and Agricultural Labor (Labor). Taking into account the natural logarithm (Ln). Equation 4 is converted to a linear logarithmic square parameter to obtain a more meaningful interpretation (Bekhet & Othman, 2018).

$$Ln(FS)_{i,t} = \alpha + \beta_1 Ln(AI_{i,t}) + \beta_2 Ln(Temp_{i,t}) + \beta_3 Prec_{i,t} + \beta_4 Ln(GDP_{i,t}) + \beta_4 Ln(FI_{i,t}) + \beta_5 GDPAgri_{i,t} + \beta_6 Labor_{i,t} + e_{i,t} \quad (4)$$

Where α is a constant, $\beta_1 - \beta_6$ are the estimated coefficients, and i and t represent the state and year, respectively. e is the *error term*. Before conducting the estimation, the dataset was preprocessed to ensure consistency across countries and years. Only countries with complete data for the 2002–2022 period were included, eliminating the need for imputation of missing values. All indicators were standardized into an annual format to align across sources (FAOSTAT and World Bank). Numerical variables were transformed using natural logarithms to reduce heteroscedasticity and facilitate elasticity interpretation (except dummy variables and data in percentage). For rainfall, raw data were converted into a decile index to capture extreme anomalies, then transformed into a dummy variable to distinguish normal from abnormal conditions. This preprocessing step ensures the transparency and replicability of the study.

To investigate the influence of agricultural investment and the climate crisis on food security, researchers used a quantitative approach with *balanced panel* data for 159 countries worldwide for the period 2002-2022, employing panel regression. The data used in this study were sourced from FAOSTAT and the World Bank. The analysis was deepened by creating panel groups based on continents, resulting in new panel groups: Africa, Asia, Europe, Oceania, North America, and South America.

4. RESULT AND DISCUSSION

The model selection between fixed effects (FE) and random effects (RE) is based on the consideration that both are commonly used alternative approaches to estimating static panel models. It should be emphasized that the Pooled OLS approach was not applied in this analysis because it was unable to capture the unobserved heterogeneity between countries. On the contrary, the FE and RE methods are designed to address these issues more appropriately (Baltagi, 2005). Therefore, it is important to determine which approach is most suitable. Based on the results of the Hausman test, evidence was obtained that the fixed effect (FE) method was more appropriate than the random effect (RE) method in the model across all panel groups (see Table 1).

Table 1. Post regression diagnostic tests.

Panel	Hausman test	Heteroscedasticity test	Autocorrelation test
	Prob.	Prob. Chi2 (Modified Wald Test)	Prob. F (Wooldridge Test)
Global	0.0000	0.0000	0.0000
Africa	0.0000	0.0000	0.0000
Asia	0.0000	0.0000	0.0000
Europe	0.0000	0.0000	0.0001
Oceania	0.0001	0.0000	0.0000
North America	0.0000	0.0000	0.0000
South America	0.0000	0.0000	0.0165

Because there is serial correlation (autocorrelation) in the model, the Prob F value of the Wooldridge test (see Table 1) indicates that the entire panel group is autocorrelated. In addition, based on the Chi-square Prob value of the Modified Wald test (see Table 2), heteroscedasticity was found across the panel group. Therefore, to address these issues autocorrelation and heteroscedasticity the fixed effects (FE) regression model was re-estimated using a heteroscedasticity and autocorrelation consistent (HAC) standard error method, clustering the standard errors based on cross-sectional data. The results of the re-estimation can be seen in Table 2.

Table 2. Regression re-estimation results after *HAC.*

VARIABLES	(1) World	(2) Africa	(3) Asia	(4) Europe	(5) Oceania	(6) North America	(7) South America
Constant	20.63*** (6.200)	29.93** (13.10)	-2.207 (15.41)	17.45*** (3.729)	13.17*** (1.968)	19.59 (13.28)	1.533 (11.07)
Agriculture investment							
LnAgriI	0.147*** (0.0113)	0.184*** (0.0178)	0.144*** (0.0234)	0.107*** (0.00852)	0.0838*** (0.00231)	0.158*** (0.0344)	0.107*** (0.0144)
Climate change							
LnTemp	-3.278*** (1.100)	-4.858** (2.310)	0.674 (2.727)	-2.710*** (0.659)	-1.797*** (0.339)	-3.148 (2.348)	-0.0631 (1.918)
Prec	-0.0175*** (0.00281)	-0.0171*** (0.00488)	-0.0214*** (0.00752)	-0.0141*** (0.00250)	-0.0184 (0.0124)	-0.0166** (0.00646)	-0.0170** (0.00672)
Control variable							
LnGDP	0.166*** (0.0291)	0.124*** (0.0379)	0.212*** (0.0618)	0.164** (0.0605)	0.0872*** (0.0100)	0.217** (0.0889)	0.281*** (0.0652)
LnFI	0.0781*** (0.0118)	0.0767*** (0.0206)	0.0702*** (0.0176)	0.0771*** (0.0153)	0.0929*** (0.0201)	0.0467 (0.0370)	0.0844*** (0.00478)
GDPAgri	0.202* (0.108)	0.190 (0.140)	0.334 (0.210)	1.277*** (0.333)	-0.335*** (0.100)	-0.749 (0.730)	0.885** (0.279)
Labor	-0.307** (0.139)	-0.233 (0.182)	-0.210 (0.214)	-0.559** (0.256)	0.341*** (0.0821)	-0.0145 (0.383)	-0.794** (0.267)
Observations	3,339	945	882	756	147	399	210
R-squared	0.826	0.860	0.805	0.841	0.603	0.799	0.960
Prob. F	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Number of Countries	159	45	42	36	7	19	10

Note: ***, **, and * signify 1%, 5%, and 10% significance levels. Robust standard errors in parentheses.

Based on Table 2, Agricultural investment improves food security in all regions, with the strongest elasticity in Africa and the weakest in Oceania. These findings align with prior studies showing positive effects of agricultural investment on productivity and food security (Ding et al., 2021; Gao et al., 2022; Kamenya et al., 2022). According to Pandey and Pandey (2023), investments in technology, machinery, and sustainable agricultural practices can increase productivity and food security. Approaches such as conservation agriculture and agroforestry support the preservation of natural resources. In addition, the development of agricultural infrastructure and research on climate-resilient varieties help reduce post-harvest losses and address climate change. Nelson et al. (2009) explains that an additional $7 billion per year is needed for research, rural infrastructure, and irrigation to address the impacts of climate change. Investment priorities vary by region: Sub-Saharan Africa on roads, Latin America on agricultural research, and Asia on irrigation efficiency.

Empirical results for each panel group show that the value of the coefficient indicates that Africa has the largest value at 0.184, while Oceania has the smallest at 0.0838. The empirical results demonstrate that Africa has the highest elasticity of agricultural investment towards food security, whereas Oceania has the lowest compared to other panel groups.

Food production in Africa is still dominated by traditional methods that are often ineffective and inappropriate in meeting the growing demand for food. This condition is exacerbated by the lack of implementation of modern practices such as food innovation technology and precision agriculture that can support higher productivity. The adoption of technology in Africa's agricultural sector is still very low, resulting in limitations in producing food sustainably (Brenya et al., 2024). Therefore, increasing agricultural investment in techniques, machinery, and technology can enhance food production more effectively and efficiently in Africa.

In Oceania, agriculture in Pacific island countries is often hampered by limited arable land, extreme weather, and saltwater intrusion into farmland, so yields are often insufficient for local needs. Countries in Oceania, especially in the Pacific islands, are more dependent on the fisheries sector than on agriculture. Fisheries are a major source of food, livelihoods, and income for local communities (Tran, Lee, & Henry, 2023). Therefore, it can be concluded that Oceania has a lower dependence on the agricultural sector in supporting food security.

Rising temperatures significantly reduce food security globally, with the strongest impacts in Africa, Europe, and Oceania, while no effect is found in Asia or the Americas. These findings align with prior studies indicating that rising temperatures significantly reduce food security in some areas (Affoh, Zheng, Dangui, & Dissani, 2022; Bedasa & Bedemo, 2023; Chandio, Gokmenoglu, Ahmad, & Jiang, 2022; Liu et al., 2023). Rising temperatures result in the proliferation of pests and pathogens in ways that can harm crop production and human health. For example, aflatoxin (a carcinogenic and immunosuppressive pathogen produced by certain fungi) may become a more common food safety concern where exposure to aflatoxin is not usually an issue, such as for corn grown in Europe (Kumar, Pathak, Bhadauria, & Sudan, 2021; Lopes, 2022), explains that with rising temperatures causing it to be less optimal for photosynthesis, reducing the duration of grain growth and increasing drought seasons, yields have stagnated for wheat, especially in Northern Europe, and barley in Southern Europe.

Extreme precipitation reduces food security globally and in most regions, with the strongest effect in Asia and the weakest in Europe; Oceania shows no significant impact. The empirical results strengthen the prior findings from Pickson and Boateng (2022); Affoh et al. (2022); Kinda and Badolo (2019) and Bedasa and Bedemo (2023). In practice, agriculture mainly uses rainwater. However, if agriculture has an excessive dependence on rainfall, it can make food production more vulnerable to changes in precipitation patterns (Akinbile, Ogunmola, Abolude, & Akande, 2020; Tankari, 2020) extreme precipitation patterns and periodic droughts can disrupt agricultural production, meaning that increasing climate risks have a serious impact on food insecurity, especially in rural areas with limited irrigation infrastructure for agricultural activities (Miheretu, 2021; Wong et al., 2020).

Empirical results related to changes in precipitation patterns in this study emphasize that when precipitation patterns change to cause drought or flooding, it will have a negative impact on food availability consistently in all regions except Oceania. Based on observations from Tran et al. (2023) countries that are located in the Pacific area face rising sea levels, combined with erosion and saltwater intrusion, which lead to flooding in homes and food gardens; ocean acidification and loss of coral reefs, which lead to the loss of fish stocks; as well as drought and loss of freshwater sources that communities rely on, impacting agriculture and freshwater for drinking.

To test the robustness of the model, we compared the regression results by changing the data of the agricultural investment variable with the lag of that variable. This step is carried out on the assumption that investment has a long-term impact. The results of the robustness regression can be seen in Table 3.

Table 3. Robust regression estimation results.

Variables	**(1)** World	**(2)** Africa	**(3)** Asia	**(4)** Europe	**(5)** Oceania	**(6)** North America	**(7)** South America
Constant	24.01*** (6.166)	33.12** (12.89)	-7.566 (13.76)	19.59*** (4.824)	13.72*** (1.947)	19.21 (13.04)	-9.609 (12.84)
Agriculture investment							
LagAgriI	0.119*** (0.0114)	0.155*** (0.0174)	0.121*** (0.0234)	0.0749*** (0.00765)	0.0841*** (0.00228)	0.109*** (0.0271)	0.0727*** (0.0173)
Climate change							
LnTemp	-3.902*** (1.091)	-5.437** (2.262)	1.619 (2.425)	-3.142*** (0.863)	-1.880*** (0.335)	-3.264 (2.286)	1.771 (2.230)
Prec	-0.0165*** (0.00266)	-0.0196*** (0.00443)	-0.0177** (0.00679)	-0.0117*** (0.00271)	-0.0254** (0.0125)	-0.0201*** (0.00549)	-0.0168** (0.00618)
Control variable							
LnGDP	0.201*** (0.0309)	0.150*** (0.0378)	0.229*** (0.0650)	0.217*** (0.0575)	0.0900*** (0.00980)	0.343*** (0.0739)	0.386*** (0.0772)
LnFI	0.0831*** (0.0126)	0.0873*** (0.0208)	0.0718*** (0.0180)	0.0736*** (0.0211)	0.0695*** (0.0217)	0.0631* (0.0360)	0.0812*** (0.00674)
GDPAgri	0.263**	0.244	0.343	1.617***	-0.249**	0.0691	1.212***

Variables	(1) World	(2) Africa	(3) Asia	(4) Europe	(5) Oceania	(6) North America	(7) South America
	(0.130)	(0.151)	(0.234)	(0.351)	(0.101)	(0.701)	(0.238)
Labor	-0.304**	-0.225	-0.228	-0.506*	0.327***	0.0707	-0.761**
	(0.145)	(0.188)	(0.226)	(0.260)	(0.0817)	(0.385)	(0.286)
Observations	3,180	900	840	720	140	380	200
R-squared	0.785	0.832	0.763	0.758	0.546	0.781	0.944
Prob. F	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Number of Countries	159	45	42	36	7	19	10

Note: ***, **, and * signify 1%, 5%, and 10% significance levels. Robust standard errors in parentheses.

The results of the estimates in Table 3, the robustness check using lagged agricultural investment confirms the main findings: agricultural investment consistently improves food security, while temperature and precipitation exert negative impacts in line with previous results. The consistency of the results between Table 2 and Table 3 shows that the estimates in Table 2 are robust.

5. CONCLUSION

This study aims to analyze the influence of agricultural investment and climate change on global and intercontinental food security. Empirical results show that rising temperatures have a significant negative impact on food security globally and in Africa, Europe, and Oceania. Changes in precipitation have a significant negative impact on all regions except Oceania. Agricultural investment has a significant positive effect on food security in all regions. However, these investments are only able to balance the impact of extreme precipitation patterns and have not been able to offset the negative impact of rising temperatures. Based on the results of the analysis, it is suggested that policies focus on increasing agricultural investment, especially for research and development to address the impacts of the climate crisis. In addition, global efforts to mitigate the climate crisis should be intensified by reducing greenhouse gas emissions, particularly CO_2, methane, and nitrogen oxides. These efforts align with the Sustainable Development Goals, especially the "Zero Hunger" target, which emphasizes eradicating hunger and achieving sustainable food security. Accordingly, this study provides empirical evidence to support the global agenda of strengthening food security through agricultural investment and climate change mitigation. This research has several limitations, including the selection of countries limited to the availability of complete data and food security, which is only proxied through the food production index. Future research should incorporate more comprehensive climate anomaly data, utilize broader indicators of food security—such as availability, access, utility, and stability—and include more detailed data on specific food production and agricultural investments where available.

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