Climate Change and Herders-Farmers Conflict as Drivers of Food Security in Nigeria: Toda-Yamamoto-Dolado-Lutkepohl Approach.

Emmanuel Umale Abbah
CEFTER, Benue State University, Makurdi/
Department of Economics, Federal University, Lokoja-Nigeria.

Naomi Onyeje Doki and **Jerome Terhemba Andohol**
Department of Economics, Benue State University, Makurdi-Nigeria.

Correspondence: emmanuel.abbah@fulokoja.edu.ng

Abstract
This research examined climate change and herders-farmers conflict as drivers of food security in Nigeria within the period 1991-2021 using the vector error correction methodology (VECM) and the Toda-Yamamoto-Dolado-Lutkepohl methodology. Climate change was proxied by carbon dioxide equivalent (CO_2e), food security was proxied by agricultural output (AQ), and herders-farmers conflict (HFC) was dummied. The findings revealed that herders–farmers conflict (HFC) is the principal driver of food security both in the short run and in the long run and further transmits positively to agricultural output (AQ) in the long run within the study period. Climate change (CO_2e) negatively influences agricultural output (AQ) both in the short run and in the long run. There is no evidence of one-on-one causality between herders-farmers conflict (HFC) and climate change (CO_2e). However, climate change (CO_2e) and other variables of interest employed in this study jointly caused herders-farmers conflict (HFC). The study recommends that the creation of ranches or grazing reserves for cattle farming in the country is key and will boost agricultural productivity. At all levels, governments should make sincere and concerted efforts to broker peace between herders and farmers and encourage the settlement of disputes through dialogue. Finally, it is crucial to constantly sensitize herders and farmers on the need for peaceful coexistence by agents of government, religious, and traditional institutions in the country.

Keywords: Climate Change, Food Security, Herders–Farmers Conflict, Toda–Yamamoto.

1. Introduction

In recent years, world food production has been predicted to grossly decline due to geometric population increases, conflicts and wars, urbanization, increased income, especially in less developed countries, and climate change. The average annual growth rate of agriculture in sub-Saharan Africa declined from 3.11% between 1991 and 2000 to 2.97% between 2001 and 2010 and 2.44% between 1971 and 2010. Furthermore, in 2007, the irrigation of arable land in Sub-Saharan Africa was 4%, while it was 29% in East Asia and 39% in South Asia (Todaro & Smith, 2015). Farmers in Africa use less than 10 kilograms of fertilizer per hectare on soils that have lost nearly all nutrients due to continuous cultivation over the years; this amount is less than the 100 kilograms used in South Asia. In sub-Saharan Africa, only 22% of farmlands grown with cereal are sown with improved varieties (Todaro & Smith, 2015). Globally, in 2019, approximately 690 million people suffered from hunger, while approximately 135 million people from 55 nations experienced serious food insecurity, 73 million of whom were from Africa. Furthermore, Africa is projected to have a 51.5% share of undernourished people by the year 2030 (Ayinde *et al.,* 2020).

Food insecurity in Nigeria seems to be on the rise. In 2013, the Global Food Security Index revealed that Nigeria came in 86th position among 107 nations. The food insecurity situation worsened in 2019, with Nigeria being ranked 94th out of 113 countries, with countries such as Ethiopia, Niger, and Cameroon being better off in terms of food security than Nigeria was. Furthermore, in 2018, 86.9 million Nigerians were found to be in abject poverty, while as of 2020, the total number of Nigerians in extreme poverty rose to 102.4 million persons. Todaro and Smith (2015) suggested that agricultural productivity is hampered by increasing temperatures, floods from heavy rains, and prolonged drought, among other factors. Herders in northern Nigeria are affected by these visible elements of greenhouse gas-induced climate change and tend to move toward the southern states of the country to get better forage for their cattle. This migration results in clashes between herders and farmers and often leads to the destruction of crops and livestock and the displacement of farmers from farming activities for as long as the conflict lasts, thus causing food insecurity. Ayinde *et al.* (2020) identified climate change as a key stressor of Nigeria's food insecurity.

Climate change seems to be a key player in the modern food supply chain, especially in sub-Saharan Africa. The agricultural sector has been observed to be heavily dependent on nature for its growth, which in turn is uncertain due to the rising rate of climate change (Idumah *et al.,* 2016). Climate change is seen as an obstacle to food security because it is capable of reducing total food production (availability of food), food access, food use, and food stability (Gregory *et al.,* 2005; Idumah *et al.,* 2016; Rojas-Downing *et al.,* 2017). The Intergovernmental Panel on Climate Change (IPCC, 2007) in its fourth assessment report predicted that less developed countries, especially Sub-Saharan African countries, would experience harsh weather conditions such as increased temperatures, rising sea levels, flooding, and drought. The IPCC report concluded that although adaptations will help, Sub-Saharan Africa will suffer most by the year 2020. The agricultural output from rain-fed agriculture is expected to decrease by 50%. A total of 75 million persons to 250 million persons will be faced with increased water stress, and freshwater lakes will also be negatively affected (Todaro & Smith, 2015).

Between 2013 and 2016, the conflict between herdsmen and farmers cost Nigeria approximately US$14 billion (Okoro, 2018 & Kwaghga, 2018). Furthermore, thousands of Nigerians currently reside in internally displaced persons (IDPs) camps, with the Benue State being the worst hit. Arson, armed robbery, rape, murder, and destruction of properties have been recorded in large numbers. Crops and livestock worth millions of naira have also been lost due to herder-farmer conflicts (Ejiogu, 2019). Eneji *et al.* (2019), Enimu *et al.* (2019), Obinna (2021), and Okafor and Chikalipah (2021) assert that conflict is the major stressor of food security in the country.

There seems to be no agreement among scholars as to the exact cause of the herder-farmers conflict that has become intense in recent years in Nigeria. Nwakanma and Boroh (2019) suggest that the intense clash between farmers and herders is attributed largely to population growth in addition to other factors ranging from variations in weather conditions to ethnicity and political strife. Traditional dispute resolution mechanisms have also not helped. Okoro (2018) suggested that the competition for land and forest resources, reprisal attacks by herders or farmers, arguments over grazing routes, cattle rustling, and the anti-grazing law in Benue State, among other factors, may be some of the likely reasons for herder-farmer conflicts in Nigeria.

Kwaghga (2018) identified land scarcity, population growth, political factors, and climate change as stressors of this conflict. Ogu (2020) named the variables that cause herder-farmer conflict in Nigeria's politics, ethnicity, cultural lifestyles, economic livelihoods, and religion. Variability in climate seems to be prominent among the variables suggested to be the reason for herder-farmer clashes in Nigeria. Thus, this research quantitatively examines the direction of causality between climate change and herders-farmers conflict in Nigeria.

Geometric population increases, conflicts and wars, urbanization, an increase in income, especially in less developed countries, and climate change are identified as stressors of food security (Todaro & Smith, 2015). Eregha *et al.* (2014), Idumah *et al.* (2016), Uger (2017), and Angba *et al.* (2020) suggested that climate change is a major driver of food security in Nigeria, while Eneji *et al.* (2019), Enimu *et al.* (2019), Obinna (2021) and Okafor and Chikalipah (2021) asserted that conflict is the major stressor of food security in the country. As such, an empirical study to ascertain these claims will be beneficial to the country to adequately apply the HRV diagnostic growth framework in finding the best solution to the problem of food insecurity in Nigeria.

Furthermore, previous research on the effect of climate variability on food security has been conflicting. Olonrunlana (2018), Angba *et al*. (2020), and Mekonnen *et al*. (2021) suggested that climate change exerts a negative influence on food security. Zakari *et al.* (2014), Ahmed *et al.* (2016) and Yusuf *et al.* (2020) found that climate change is a positive driver of food security. Furthermore, Eregha *et al*. (2014), Ibekwe *et al.* (2015), Idumah *et al.* (2016), and Eshete *et al*. (2020) suggested that climate change exhibits asymmetry because its effect on food security is both positive and negative.

Therefore, this research sought to investigate the causality between climate change and herders-farmers conflict in Nigeria. Additionally, the study examines the transmission channel from climate change and herder-farmer conflict toward maintaining optimum food security in the country. The main driver of food security in Nigeria was also investigated within the study period. The incessant clashes between herders and farmers in Nigeria, in addition to the threat posed to food security by climate change, have motivated researchers to embark on this topic.

2. Literature Review

2.1 Conceptual Review

2.1.1 Food Security

Idumah *et al.* (2016) defined food security as a situation in which the citizens of a particular country have access to the right quantity of food at all times and where there is no malnutrition, undernourishment, or fear of famine. The World Food Summit (1996) referred to food security as access to adequate, safe, and nutritious food to live healthily. According to Ojuederie and Ogunsola (2017), when people live healthily as a result of having the ability to acquire a sufficient, safe, nutritious, and balanced diet for their existence and the survival of others, the country in question is said to be food secure.

Food security is generally built around four pillars: access to food, food availability, food use, and food stability. Thus, for the sake of this study, food security is defined as availability in terms of quantity, amount of crop output, livestock output, fishery output, and forest resource output for consumption by humans and other uses. Food security in this study is proxied by agricultural gross domestic product in Nigeria.

2.1.2 Climate Change

Todaro and Smith (2015) defined climate change as changes in nature that cause a decrease in annual rainfall, increased annual temperature, and increased drought and flooding, which seem to be consistent or even continue unabated, causing untold hardship to human and animal life. The accumulation of greenhouse gas (GHG) emissions in the atmosphere is a major source of climate variability. These gases are primarily composed of carbon dioxide (CO_2), nitrous oxide (N_2O) and methane (CH_4). Carbon dioxide is released into the environment from the activities of farmers in the process of crop production through deforestation, burning of biomass, and plant remnants, among others. The use of fertilizers in the production of crops produces a considerable amount of nitrous oxide (N_2O) emissions. Excretion and the digestive activities of livestock release substantial amounts of nitrous oxide and methane, respectively, into the ozone, thereby causing global warming (Eshete *et al.,* 2020).

The Intergovernmental Panel on Climate Change (IPCC), 2007, defined climate change as measurable and substantial changes in the climatic conditions of a place over some time, usually over several decades. Ojuederie and Ogunsola (2017) see climate change as the alteration of weather conditions over a long period, resulting in changes in the pattern of rainfall, temperature, flooding, desertification, land degradation, and erosion. This study defines climate change as the total greenhouse gas emissions in the atmosphere, which are collectively measured in a single unit by carbon dioxide equivalent (CO_{2e}). These gases cause alterations in weather conditions (increased temperature, rise in sea level, flooding, drought, and variation in rainfall) in particular geographical areas, which affect food security.

2.1.3 Herders–Farmers Conflict

Nwankwo *et al.* (2019) assert that herders are nomadic ones who rear cattle and, in the process, tend to conquer communities through forceful means and make them permanently abode. Mufutau *et al.* **(**2020) suggested that herders, such as Fulani herdsmen or pastoralists, are mostly nomadic or seminomadic and are known for conflicting with crop producers in Nigeria. Farmers, on the other hand, are considered individuals who carry out agricultural activities involving crop farming on either a small scale or a large scale and whose crops are always destroyed by herders (Mufutau *et al.,* 2020).

This study sees herders–farmers'farmers' conflict as the result of disagreements between cattle rearers, who are mostly Fulani Muslims from northern Nigeria who move in large numbers toward the southern region seeking greener pastures for their cattle, and farmers, who are mostly farmers who cultivate crops on their ancestral lands for consumption and sale. These disagreements often involve grazing routes, destruction of crops by herders, cattle rustling, and mysterious death of cattle, among others. Often, this conflict involves the death of large numbers of people, the destruction of farmlands and property, the death of livestock, and the destruction of crops on farms and stored ones, among others.

2.2 Theoretical Framework

The Hausmann–Rodrick–Velasco (HRV) growth diagnostic theory (2005) states that the major challenges facing a country need to be ordered and addressed from the most binding obstacle. Developing countries, especially Nigeria, which are faced with multifaceted developmental challenges such as herder-farmer conflicts, climate change, and food insecurity, can rely on the HRV framework for fast-tracking their economic development. Solow growth theory (1957) states that economic growth is determined by three factors: labour, capital, and technology. Solow extended the Cobb–Douglas production function (1928) and opined that in addition to labour and capital, a third factor, technology referred to as the Solow residual, contributes meaningfully to economic growth.

This study adopted the Solow growth theory, as it states that agricultural inputs (technological change inclusive) determine agricultural output. This theory is appropriate because climate change (CO_2e), herder-farmer conflict (HFC), employment in agriculture (EA), arable land (AL), and commercial bank loans and advances in agriculture (CBLA) are determinants (inputs) of agricultural output (AQ) proxied by gross domestic product in agriculture.

2.3 Empirical Review

2.3.1 Review of the Climate Change-Food Security Nexus

Using the vector error correction model (VECM), Eregha *et al.* (2014) investigated the influence of climate variability on crop productivity in Nigeria (1970-2009). Findings from the study revealed that the influence of the regressors (carbon dioxide, temperature, and rainfall) on yam yield is asymmetric depending on the type of crop, climate change variable, and duration of maturity of the crop. Idumah *et al.* (2016) examined climate variability and food output in Nigeria from 1975-2010. The study employed the vector error correction model (VECM) and findings from the study revealed that rainfall positively and significantly influenced food output in the short term. However, it negatively influenced food output in the long run. Mehmood *et al.* (2016) empirically investigated the factors that affect the output of agriculture in Pakistan from 1990 to 2016. Using the autoregressive distributed lag (ARDL) methodology; the findings of the study revealed that rainfall directly influenced agricultural productivity, while employment in agriculture positively but insignificantly influenced agricultural output in the long run.

Furthermore, moderate rainfall and temperature were found to be positively correlated with yam yield, while extreme climate negatively affected production after employing a multilinear regression model and descriptive analysis by Uger (2017) in examining the effect of climate change on yam production in Benue State. By employing the nonlinear autoregressive distributed lag (NARDL) methodology to examine the influence of climate variability on crop output in Nigeria from 1990 to 2020, Alehile *et al*. (2022) found that the effect of climate variability on crop output is both direct and inverse in the short run, while in the long run, climate variability negatively influences crop output. This research advocated for the provision of irrigation systems to enhance crop yield in Nigeria.

2.3.2 The Impact of Conflict on Food Security in Nigeria

Eneji *et al.* (2019) examined the influence of insecurity on agricultural output in Nigeria through the case study of Gombe State. The study employed the ordinary least squares (OLS) methodology and the findings of the study revealed that poverty and government expenditures on security have a direct relationship with agricultural GDP. However, unemployment and crime rates are inversely related to agricultural GDP. The industrialization of the agricultural sector in addition to the provision of a peaceful environment that encourages farming was advocated. Analyzing the influence of insecurity on agricultural output in Nigeria from 1960 to 2017, Enimu *et al.* (2019), while using the vector error correction model (VECM), found that Boko Haram insurgency, Herders-farmers clashes, ethno-religious crises, and Niger Delta militancy negatively influenced agricultural GDP. Government funding for agriculture should be farmer-specific, while adequate security must be provided to enhance agricultural output.

Kwaghtser (2019) investigated the effect of the clashes between herdsmen and farmers on food output in Benue State using descriptive and inferential statistical approaches. The findings revealed a significant negative effect of the conflict on food production in the area of the study and suggested that the government should provide relief materials and food items to victims of this conflict. Obinna (2021) examined the relationship between human capital, security, and agricultural output in Nigeria from 1981 to 2017. Findings from the study revealed that government expenditure on security, health, and education positively influenced agricultural productivity in the study area, with an insignificant effect. Life expectancy was revealed as a major determinant of agricultural productivity. Using the autoregressive distributed lag (ARDL) technique, the study advocated for improved healthcare and the provision of adequate security for lives and property. To further reveal the effect of conflict on food security, Okafor and Chikalipah (2021) investigated the influence of terrorism on agricultural output in Nigeria from 1971 to 2019. The findings revealed that terrorism is inversely and significantly related to agricultural output in Nigeria. The study employed the ordinary least squares (OLS) technique while advocating that the security of farmers be the government's top priority while encouraging herders to practice modern methods of cattle rearing.

2.3.3 Research Gap

This study is novel as it empirically investigated the transmission channel of climate change and herders-farmers conflict towards maintaining optimum food security in Nigeria, while also ascertaining the major driver of food security in Nigeria through the use of the vector error correction methodology (VECM) and the Toda-Yamamoto-Dolado-Lutkepohl (TYDL) methodology. The stationarity of employment in agriculture (EA) at I(1) after a structural break justifies the use of VECM, while the mixed order of integration I(1) and I(2) justifies the use of the TYDL approach for Granger causality analysis of the variables of interest. Reviewed studies on the influence of climate variability on food output in Nigeria have focused on carbon dioxide emissions. The total effect of greenhouse gases on food security is ignored by the studies reviewed. In this study, climate change is proxied by the carbon dioxide equivalent (a better measure of climate change).

3. Methodology

The Augmented Dickey-Fuller (ADF) and Kwaitkowski-Phillips-Schmidt-Shin (KPSS) tests were employed to check for unit roots. To examine the influence of climate variability, the conflict between herders and farmers on food availability in Nigeria, the vector error correction methodology (VECM) was used, while the Toda–Yamamoto–Dolado–Lutkepohl (TYDL) methodology was used to test for Granger causality. The Johansen cointegration test was used to check for long-term relationships. The serial correlation test and the inverse root stability test were also employed. The Central Bank of Nigeria's Statistical Bulletin (2021) and the World Bank Development Indicator (2021) are sources from which the data for this research were obtained (1991 to 2021).

3.1 Model Specification

The Toda–Yamamoto framework and the given lag-augmented VAR ($k + d_{max}$) for the agricultural output (AQ) and climate change (CO_2e) nexus are given below:

$$AQ_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i}\, AQ_{t-i} + \sum_{j=k+1}^{k+d_{max\,2}} \alpha_{2j}\, AQ_{t-j} + \sum_{i=1}^{k} \beta_{1i}\, \mathrm{CO2e}_{t-i} + \sum_{j=k+1}^{k+d_{max\,2}} \beta_{2j}\, \mathrm{CO2e}_{t-j} + \varepsilon_{1t} \qquad (1)$$

$$CO2e_t = \beta_0 + \sum_{i=1}^{k} \beta_{1i}\, CO2e_{t-i} + \sum_{j=k+1}^{k+d_{max\,2}} \beta_{2j}\, CO2e_{t-j} + \sum_{i=1}^{k} \alpha_{1i}\, \mathrm{AQ}_{t-i} + \sum_{j=k+1}^{k+d_{max\,2}} \alpha_{2j}\, \mathrm{AQ}_{t-j} + \varepsilon_{1t} \qquad (2)$$

H_0: $\lambda_1 = \lambda_2 = 0$, H_1: CO_2e does not Granger-cause AQ.
H_0: $\alpha_1 = \alpha_2 = 0$, H_1: AQ does not Granger-cause CO_2e.

Furthermore, the Toda–Yamamoto framework of agricultural output (AQ) and herders–farmers conflict (HFC) nexus is presented below. where *HFC* = herders-farmers conflict (dummy variable), 0 = before the ranking of Fulani herdsmen as the fourth world's most deadly terrorist group according to the Global Institute for Economics and Peace using the Global Terrorism Index (GTI), and 1 = period after the ranking.

$$AQ_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i}\, AQ_{t-i} + \sum_{j=k+1}^{k+d_{max\,2}} \alpha_{2j}\, AQ_{t-j} + \sum_{i=1}^{k} \beta_{1i}\, \mathrm{HFC}_{t-i} + \sum_{j=k+1}^{k+d_{max\,2}} \beta_{2j}\, \mathrm{HFC}_{t-j} + \varepsilon_{1t} \qquad (3)$$

$$HFC_t = \beta_0 + \sum_{i=1}^{k} \beta_{1i}\, HFC_{t-i} + \sum_{j=k+1}^{k+d_{max\,2}} \beta_{2j}\, HFC_{t-j} + \sum_{i=1}^{k} \alpha_{1i}\, \mathrm{AQ}_{t-i} + \sum_{j=k+1}^{k+d_{max\,2}} \alpha_{2j}\, \mathrm{AQ}_{t-j} + \varepsilon_{1t} \qquad (4)$$

H_0: $\lambda_1 = \lambda_2 = 0$, H_1: HFC does not Granger-cause AQ.
H_0: $\alpha_1 = \alpha_2 = 0$, H_1: AQ does not Granger-cause HFC.
Finally, the Toda–Yamamoto framework of climate change (CO_2e) and herders–farmers conflict (HFC) nexus is presented below:

$$CO2e_t = \alpha_0 + \sum_{i=1}^{k} \alpha_{1i}\, CO2e_{t-i} + \sum_{j=k+1}^{k+d_{max\,2}} \alpha_{2j}\, CO2e_{t-j} + \sum_{i=1}^{k} \beta_{1i}\, \mathrm{HFC}_{t-i} + \sum_{j=k+1}^{k+d_{max\,2}} \beta_{2j}\, \mathrm{HFC}_{t-j} + \varepsilon_{1t} \qquad (5)$$

$$HFCet = \beta_0 + \sum_{i=1}^{k} \beta_{1i}\, HFC_{t-i} + \sum_{j=k+1}^{k+d_{max\,2}} \beta_{2j}\, HFC_{t-j} + \sum_{i=1}^{k} \alpha_{1i}\, \mathrm{CO2e}_{t-i} + \sum_{j=k+1}^{k+d_{max\,2}} \alpha_{2j}\, \mathrm{CO2e}_{t-j} + \varepsilon_{1t} \qquad (6)$$

H_0: $\lambda_1 = \lambda_2 = 0$, H_1: HFC does not Granger-cause CO_2e. H_0: $\alpha_1 = \alpha_2 = 0$, H_1: CO_2e does not Granger-cause HFC.

4. Results and Discussion

Table 1: Descriptive statistics

	AQ	CO_2e	EA	AL	CBLA
Mean	10300.69	243836.6	43.53430	73.70091	254.1121
Maximum	18738.41	349873.3	50.57000	76.43350	1457.822
Minimum	3590.840	189750.0	33.89667	70.19225	5.010000
Jarque-Bera	2.887062	4.927435	2.928288	1.295784	34.53025
Probability	0.236093	0.085118	0.231276	0.523147	0.000000
Observations	**31**	**31**	**31**	**31**	**31**

Source: Extracts from Eviews 10, (2022).

Table 1 reveals that between 1991 and 2021, agricultural output (AQ), carbon dioxide equivalent (CO_2e), employment in agriculture (EA), arable land (AL), and commercial bank loans and advances in agriculture (CBLA) averaged ₦10300.69 billion, 243836.6 kilotonnes of CO_2 equivalent, 43.53%, 73.70% and ₦254.11 billion, respectively. The highest values of AQ, CO_2e, EA, AL, and CBLA within the period of the study were associated with ₦18738.41 billion, 349873.3 kilotonnes of CO_2 equivalent, 50.57%, 76.43% and ₦1457.82 billion, respectively. The lowest values of AQ, CO_2e, EA, AL, and CBLA were associated with ₦3590.84 billion, 189750 kilotonnes of CO_2 equivalent, 33.89%, 70.19%, and ₦5.01 billion, respectively.

Employment in agriculture (EA) had its maximum and minimum values in 1991 and 2021, respectively. This may not be connected with the increasing level of insecurity in the country, especially during the herders-farmers conflict. This conflict has displaced a good number of farmers previously engaged in agricultural activities. Conflicts in Nigeria seem to have continuously reduced labour in the agricultural sector. The availability of arable land (AL), with its maximum value in 2021 and minimum value in 1991, is closely related to employment in agriculture (EA). Additionally, this may not be connected with the abandonment of arable land (AL) as a result of conflicts between herders and farmers or the insecurity of lives and property in the country.

The resolve of the government to revamp the agricultural sector through various agricultural policies over the years included the Agricultural Transformation Agenda (ATA) between 2011 and 2015 and its extension through the Agriculture Promotion Policy (APP) between 2016 and 2020, which mandates commercial banks to finance the Growth Enhancement Scheme (GES) and boost lending to agriculture from 1% to 6% of all formal credit may have accounted for the lowest and highest values of Commercial Bank Loans and Advances in Agriculture (CBLA) in 1991 and 2021, respectively. Agricultural output (AQ) had its highest value in 2021 and its lowest value in 1991. This may not be connected with the desire of the government to substitute importation and dependence on other countries for food supplies to become self-sufficient in food production through the provision of funding, improved seeds, and fertilizers, among other benefits, to farmers. The return to democratic rule in 1999 and the increasing agricultural and industrial development of the country may have accounted for the lowest and highest values of carbon dioxide equivalent (CO_2e) in 2000 and 2021, respectively. The Jarque–Bera test indicates that the observations are not completely normal; hence, the need to proceed with testing for unit roots, as presented in Table 2.

Table 2: Summary of unit root tests

Variables	ADF t-test @ level	Mackinnon Critical Value @ 5%	ADF t test @ 1st/2nd difference	Mackinnon Critical Value@ 5%	Order of Integration
AQ	-0.806928	-2.963972	-4.954743	-2.967767	1(1)
CO_2e	1.145026	-2.963972	-4.515908	-2.967767	1(1)
EA	-0.207436	-2.967767	-5.046460	-2.971853	1(2)
AL	-0.593244	-2.967767	-4.324711	-2.967767	1(1)
CBLA	-0.894055	-2.963972	-6.185596	-2.967767	1(1)

Variables	KPSS t-test @ level	Mackinnon Critical Value @ 5%	KPSS t test @ 1st/2nd difference	Mackinnon Critical Value @ 5%	Order of Integration
AQ	0.701003	0.463000	0.174273	0.463000	1(1)
CO_2e	0.611535	0.463000	0.338386	0.463000	1(1)
EA	0.711522	0.463000	0.271472	0.463000	1(2)
AL	0.742009	0.463000	0.376572	0.463000	1(1)
CBLA	0.741659	0.463000	0.155745	0.463000	1(1)

Note: if t*≤ADF (critical values) = the unit root does not exist.
Source: Extracts from Eviews 10, (2022)

Table 2 reveals the results of the unit root tests (both the ADF and the KPSS). Variables are integrated into order one I(1) except for employment in agriculture (EA), which is integrated into order two I(2) but becomes I(1) after a structural break is identified and removed. The order of integration I(2) prompted the use of the Toda–Yamamoto approach involving the use of the vector autoregressive methodology for Granger causality, while I(1) prompted the use of the vector error correction methodology for the transmission mechanism in the variables of interest. However, the research proceeded to determine the optimal lag, as presented in Table 3.

Table 3: Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	53.98364	NA	1.64e-09	-3.198909	-2.918670	-3.109258
1	278.8775	344.8372*	5.88e-15*	-15.79183*	-13.83016*	-15.16427*

Note: * indicates the lag order selection criterion. The Akaike information criterion (AIC) was utilized in this study.

Source: Extracts from Eviews 10, (2022).

Table 3 presents the lag order selection criteria, which suggest that lag 1 is the appropriate lag length. Thus, further testing was performed using lag 1.

Table 4: Unrestricted Cointegration Rank Test (Trace) and Maximum Eigenvalue

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical value	Prob.**
None *	0.773693	123.1221	95.75366	0.0002
At most 1 *	0.593281	80.03216	69.81889	0.0061
At most 2 *	0.535188	53.94278	47.85613	0.0120
At most 3 *	0.404303	31.72523	29.79707	0.0296
At most 4 *	0.308030	16.70255	15.49471	0.0328
At most 5 *	0.187579	6.024360	3.841466	0.0141
Note: Trace test indicates 6 co-integrating equations at 0.05 level				
Hypothesized No. of CE(s)	**Eigenvalue**	**Max-Eigen Statistic**	**0.05 Critical value**	**Prob.****
None *	0.773693	43.08997	40.07757	0.0222
At most 1	0.593281	26.08938	33.87687	0.3153
At most 2	0.535188	22.21755	27.58434	0.2094
At most 3	0.404303	15.02268	21.13162	0.2873
At most 4	0.308030	10.67819	14.26460	0.1711
At most 5 *	0.187579	6.024360	3.841466	0.0141
Note: Max-eigenvalue test indicates 1 cointegrating equation at 0.05 level				

Source: Extracts from Eviews 10, (2022)

Table 4 shows the results of the cointegration test. The trace and max-eigenvalue tests revealed 6 and 1 cointegrating equations at the 0.05 level, respectively. The Granger noncausality test is further employed to confirm the long-run relationship. The Granger noncausality test results are presented in Table 5.

Table 5: VEC Granger Causality/Block Exogeneity Wald tests

Dependent variable: LNAQ			
Excluded	**Chi-sq**	**Df**	**Prob.**
LNCO2E	0.001276	1	0.9715
HFC	1.435334	1	0.2309
EA	0.793254	1	0.3731
AL	0.449232	1	0.5027
LNCBLA	0.043293	1	0.8352
All	**3.862713**	**5**	**0.5693**
Dependent variable: LNCO2E			
LNAQ	0.036759	1	0.8480
HFC	0.785535	1	0.3755
EA	0.198538	1	0.6559
AL	0.027721	1	0.8678
LNCBLA	0.383456	1	0.5358
All	**2.713503**	**5**	**0.7441**

Dependent variable: HFC			
LNAQ	5.592473	1	0.0180
LNCO2E	0.757649	1	0.3841
EA	9.603899	1	0.0019
AL	0.964632	1	0.3260
LNCBLA	1.461955	1	0.2266
All	**11.43589**	**5**	**0.0434**
Dependent variable: EA			
LNAQ	2.414857	1	0.1202
LNCO2E	0.266302	1	0.6058
HFC	7.577109	1	0.0059
AL	0.018145	1	0.8928
LNCBLA	1.845939	1	0.1743
All	**17.61619**	**5**	**0.0035**

Source: Extracts from Eviews 10, (2022).

Table 5 reveals that unidirectional causality runs from agricultural output (AQ) to herders-farmers conflict (HFC) and not from herders-farmers conflict (HFC) to agricultural output (AQ). Bidirectional causality runs from employment in agriculture (EA) to herders-farmers conflict (HFC) and from herders-farmers conflict (HFC) to employment in agriculture (EA). There is no evidence of one-on-one causality between herders-farmers conflict (HFC) and climate change (CO_2e). However, climate change (CO_2e) and other variables of interest employed in this study jointly caused herders-farmers conflict (HFC). A probability value of less than 5 percent (0.05) indicates the rejection of Granger noncausality and the acceptance of causality between the variables of interest, respectively. The Granger non-causality test supersedes the traditional causality test primarily because it enables the testing of the joint influence of the variables of interest on a dependent variable through the use of the Wald test.

Table 6: Impulse response function (response to agricultural output)

Period	LNAQ	LNCO2E	HFC	EA	AL	LNCBLA
2	0.012352	-0.002956	-0.002852	-0.003200	-0.000104	0.002289
6	0.024759	0.029846	-0.042657	-0.010770	-0.000733	0.016141
10	0.009575	-0.000857	0.044691	0.023698	0.000671	0.014748

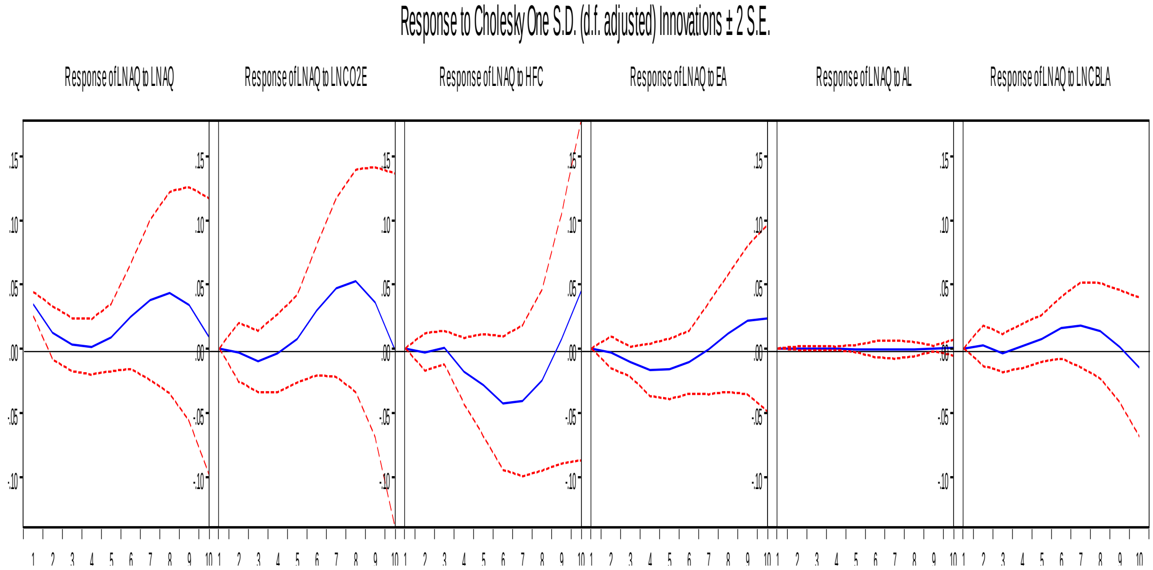
Source: Extracts from Eviews 10, (2022).

Table 6 reveals the impulse response function of agricultural output (AQ) to innovations in the independent variables of the study. Agricultural output (AQ) responds positively to shocks throughout the time horizon. Agricultural output (AQ) reacts negatively to climate change, proxied by the carbon dioxide equivalent (CO_2e), both in the short run and in the long run. Innovations to herders-farmers conflict (HFC) cause a negative trend in agricultural output (AQ), which later turns positive in the long run. This response of agricultural output (AQ) to herders-farmers conflict (HFC) is replicated by positive shocks to employment in agriculture (EA) and arable land (AL). Finally, agricultural output (AQ) responds positively to shocks from commercial bank loans and advances in agriculture (CBLA) in the short run but reacts negatively in the long run. This may not be unconnected with the increasing negative influence of herder-farmer conflict on agricultural productivity, which has limited farmers' engagement in farming activities due to the fear of being attacked.

The reaction of agricultural output (AQ) to innovations in climate change (CO_2e) agrees with the *a priori* and the works of Idumal *et al.* (2016), Olonrunlana (2018), Angba *et al*. (2020) and Mekonnen *et al*. (2021) but disagrees with the works of Zakari *et al.* (2014), Ahmed *et al.* (2016) and Yusuf *et al.* (2020). This could be because, despite warnings and projections from the Intergovernmental Panel on Climate Change (IPCC) and other expert bodies concerning the devastating influence of climate variability on food availability, the efforts of the Nigerian government are still not visible.

The reaction of agricultural output (AQ) to innovations in herders-farmers conflicts (HFCs) agrees with what was previously reported and with the findings of Enimu *et al.* (2019), Kwaghtser (2019), and Okafor and Chikalipah (2021). However, the positive reaction of agricultural output (AQ) to herders-farmers conflict (HFC) in the long run is likely to occur due to the building of grazing reserves currently being proposed by the government for the rearing of cattle in Nigeria. This will not only put an end to the degenerating conflict between herders and farmers but also add value to the quality of cattle reared in the country and, on the other hand, enable farmers to go to their farms freely and thus increase productivity.

Fig 1: Graph of the Response of LNAQ to Innovations



Source: Extract from Eviews 10, 2022.

Figure 1 provides a graphical illustration and explicit backing to Table 6. The graph further reveals that the transmission channel from climate change to agricultural output is both negative and positive, as one observes the reaction of agricultural output from periods 1 to 10. This result agrees with the findings of Eregha *et al*. (2014), Ibekwe *et al.* (2015), Ahmed *et al.* (2016), Idumah *et al.* (2016), and Eshete *et al*. (2020). Herders-farmers conflict (HFC) has both negative and positive influences on agricultural output (AQ). The likely reason is that the cattle ranches proposed by the government if implemented, will be beneficial to both herders and farmers in the long run.

Another salient point from this graph is that the reaction of agricultural output (AQ) to innovations from arable land (AL) remains almost insignificant. This may not be unconnected to the lack of industrialization of the agricultural sector in Nigeria.

Table 7: Variance decomposition (response to agricultural output)

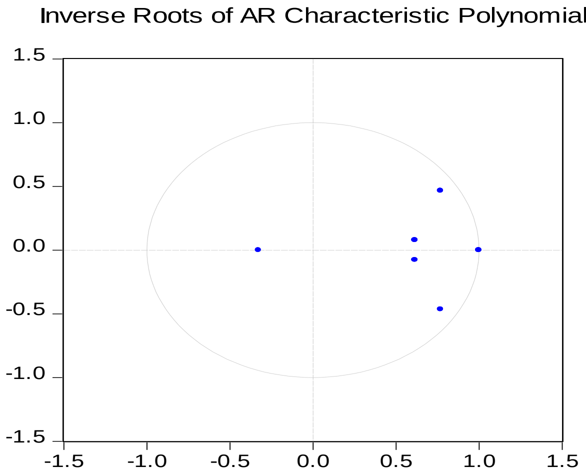
Period	S.E	LNAQ	LNCO2E	HFC	EA	AL	LNCBLA
2	0.035502	97.48518	0.076724	1.568826	0.710711	0.009867	0.148696
6	0.047058	56.76636	1.135261	29.81239	10.60648	0.104489	1.575020
10	0.052523	47.64024	4.575361	35.06177	9.972752	0.171100	2.578776

Source: Extracts from Eviews 10, 2022.

Table 7 reveals the variance decomposition of agricultural output (AQ) to innovation from the regressors employed in the research. In the short run, climate change, proxied by carbon dioxide equivalent (CO_2e), herders-farmers conflict (HFC), employment in agriculture (EA), arable land (AL), and commercial bank loans and advances in agriculture (CBLA), accounted for 0.08%, 1.57%, 0.71%, 0.00%, and 0.15%, respectively, of the fluctuations in agricultural output (AQ). In the long run, CO_2e, HFC, EA, AL, and CBLA accounted for 4.58%, 35.06%, 9.97%, 0.17%, and 2.58%, respectively, of the fluctuations in agricultural output (AQ). This result implies that herders–farmers conflict (HFC) is the principal driver of agricultural output (AQ) both in the short run and in the long run and agrees with the work of Kwaghtser (2019). Thus, when applying the HRV diagnostic framework (which is key to this research) to solve the problems of Nigeria's agricultural sector, herders-farmers conflict (HFC) needs to be prioritized and addressed swiftly.

Post diagnostic Estimates

Figure 2: Inverse Root Stability Test



Source: Extract from Eviews 10, 2022.

Figure 2 presents the results of the inverse root stability test. The test revealed that the variables used in the model of this paper are stable and appropriate for forecasting. The serial correlation test, which is another postdiagnostic test used in this paper, is presented in Table 8.

Table 8: VAR Residual Serial Correlation LM Tests

Lag	LRE* stat	Df	Prob.	Rao F-stat	Df	Prob.
1	40.21704	36	0.2889	1.093761	(36, 20.3)	0.4251

Source: Extracts from Eviews 10, 2022.

Table 8 reveals the absence of autocorrelation in the variables of interest used in this research, which is desirable.

5. Conclusion and Recommendations

This study examined the influence of climate change and herder-farmer conflict on food security in Nigeria from 1991 to 2021. The incessant conflicts between herders and farmers in Nigeria, in addition to the threat posed to food security by climate change, motivated the researchers to embark on this topic. Climate change, proxied by the carbon dioxide equivalent (CO_2e), negatively influences food security, proxied by agricultural gross domestic product (AQ), both in the short run and long run. Herders-farmers conflict (HFC) negatively influences agricultural output (AQ) in the short run. However, its impact in the long run is positive. Furthermore, herder-farmer conflict (HFC) was the principal driver of agricultural output (AQ) in Nigeria within the period of the study. Finally, there is no evidence of one-on-one causality between herders-farmers conflict (HFC) and climate change (CO_2e). However, climate change (CO_2e) and other variables of interest employed in this study jointly caused herders-farmers conflict (HFC). Time and financial constraints were obstacles to the successful completion of this research.

The study recommends the following: (i) The current herders–farmers conflicts should be resolved amicably as soon as possible by the federal government through the creation of proposed grazing reserves or ranches, as this will boost agricultural productivity in Nigeria. (ii) At all levels, the government should make sincere and concerted efforts to broker peace between herders and farmers and encourage disputes through dialogue. (iii) The constant sensitization of herders and farmers to the need for peaceful coexistence by agents of government, religious, and traditional institutions in the country.

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