EFFECTS OF CLIMATE CHANGE AND HERDERS-FARMERS CONFLICT ON FOOD SECURITY IN NIGERIA.

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Abstract
Using the Pearson Product Moment Correlation and the Autoregressive Distributed Lag (ARDL) methodology, this study examined the effect of climate change and herders-farmers conflict on food security in Nigeria between 1983 and 2021. The findings of the study revealed that climate change throughout the study negatively and significantly influenced food security proxied by crop production both in the short-run and long run. While the herders-farmers conflict negatively influenced crop production, its influence remained insignificant both in the short-run and long-run. Climate change both in the short-run and long-run is inversely related to food security proxied by livestock production. However, its influence remained insignificant. Furthermore, herders-farmers conflict positively but insignificantly influenced livestock production during the duration of this study. Thus, crop production is the most hit aspect of food security by the herders-farmers conflict in Nigeria. Finally, climate change is highly correlated to the herders-farmers conflict in Nigeria. The study adopted the neoclassical theory of production and recommended that climate-smart agriculture needs to be encouraged in addition to the provision and use of improved varieties of crops that can withstand the adverse effects of climate change. Furthermore, the free-range method of cattle rearing should be reconsidered and appropriate measures taken to ranch cattle since the herders-farmers conflict favours livestock production to the detriment of crop production in Nigeria. Finally, the government should make concerted efforts to find the actual cause of the conflict between herders and farmers and resolve it to guarantee food security.

Keywords: Carbon dioxide equivalent, Climate Change, Food Security, and Herders-Farmers Conflict. **JEL Classification:** Q54, E23, F52.

1. INTRODUCTION

Todaro and Smith (2015) assert that the average annual growth rate of agriculture in developing countries of the world was higher between 1971 and 2010 when compared to the growth rates of high-income countries and that of transition countries. This progress in the agricultural sector is said to be unevenly distributed as some parts of the developing world especially Sub-Saharan Africa are faced with geometric population increase which puts constant pressure on available land thereby reducing its nutrients and thus decreasing crop yield. Wars and conflicts, climate change, urbanization, and rise in income are other factors responsible for the rising shortages in food supply across the globe (Todaro & Smith, 2015). In addition, the non-use of improved varieties of seeds, inadequate use of fertilizer, absence of irrigation systems, and other essentials of modern agriculture have further exposed Africa to food insecurity.

Ayinde et al. (2020) opined that on the global front about 690 million persons suffered from food insecurity in 2019. Fifty-five (55) nations around the world with a population of about 135 million persons faced severe hunger in 2019 with 73 million of this number from the African continent. In 2011, about 270 million people out of Africa's 750 million people suffered from one form of malnutrition or the other as a result of inadequate food supplies (Todaro & Smith, 2015). In 2013, Nigeria which used to be a major exporter of agricultural goods was ranked 86th out of 107 countries on the global food security index. In 2019, the food insecurity situation deteriorated further with Nigeria being ranked 94th out of 113 countries in the world Ayinde et al. (2020).

Todaro and Smith (2015) identified climate change and conflict as major determinants of food security especially in Sub-Saharan Africa where adaptive capacities to the adverse effects of climate change seem to be non-existent, in addition to constant conflicts between and within nations. Idumah et al. (2016) opined that the agricultural sector in Nigeria is heavily dependent on the variability of climate change for its productivity. Oli et al. (2018) posit that in Nigeria, extreme weather conditions in the northern parts of the country have been responsible for the mass movement of herders down south for greener pastures for their cattle. Eneji *et al.* (2019), Enimu *et al.* (2019), Obinna (2021), Okafor and Chikalipah (2021); and Tersoo and Ogochukwu (2014) agree with Todaro and Smith (2015) that herders-farmers conflict is a major determinant of food security.

Kwaghga (2018) asserts that the herder-farmer conflict spiked between 2013 and 2014. The number of persons killed as a result of this conflict increased astronomically from 63 persons in 2013 to 1229 persons in 2014, prompting the Institute for Economics and Peace using the global terrorism index (GTI) to rank the herdsmen as the fourth world's most deadly terrorist group after Al-Shabab, Islamic State of Iraq and Syria (ISIS) and Boko Haram (Okoro, 2018). A good number of farmers in Nigeria are presently residing in various Internally Displaced Persons (IDPs) camps with the herders perpetually occupying the rural dwellings of the farmers. This conflict is more prevalent in North Central Nigeria with Benue State being the most vulnerable. Crops and livestock worth millions of naira have also been lost due to this conflict (Ejiogu, 2019).

The works of Angba *et al.* (2020); Mekonnen *et al.* (2021); Yusuf *et al.* (2021); and Eshete *et al.* (2020) are all in disagreement as regards the direction of the effect of climate change on food security. In as much as Eneji *et al.* (2019), Enimu *et al.* (2019), Obinna (2021), and Okafor and Chikalipah (2021) assert that conflict is a determinant of food security in Nigeria, the aspect of food security that is most affected by the on-going herders-farmers conflict is in dispute among researchers. While Umeh and Chukwu (2016) opined that the livestock sub-sector is most affected, Adelakun et al. (2015) assert that the crop sub-sector is the most hit.

Nigeria as a country has battled endlessly with the menace of insecurity especially the herders-farmers conflict which is responsible for the abandonment of agricultural lands and displacement of farmers from farming activities. This conflict has taken a toll on the food security drive of various government regimes in the country. Food prices continue to rise and this is accompanied by the high rate of food importation to augment the shortages being experienced in the country. Nigeria has been observed to be very far away from being food secure as the conflicts that have kept farmers out of business have been reinforced by the effects of climate change. From the late onset of the rainy season to the early cessation of rains, from drought to flooding, compounded by the over-reliance of farmers on rain-fed agriculture without adequate irrigation farming, inadequate use of climate-resistant varieties of crops; and generally, the poverty rate among Nigerian farmers (Abbah et al., 2023). It is glaring that food insecurity is still far from being curtailed in Nigeria. This study, therefore, examined the effect of climate change and herders-farmers conflict on food security in Nigeria. Furthermore, the study ascertained the aspect of food security that is most affected by the ongoing herder-farmers conflict in Nigeria. And finally, the study investigated the degree of correlation between climate change and herders-farmers conflict in Nigeria.

2. LITERATURE REVIEW

2.1 Conceptual Review

2.1.1 Food Security

The World Food Summit (1996) defined food security as the access to adequate, safe, and nutritious food to live healthily by the people. Furthermore, Idumah et al. (2016) posit that food security is a situation where there is the absence of undernourishment or the fear of a shortage of food. Food security guarantees that people have access to the right quantity of food at the right time. Food availability, food access, food stability, and food use are the four pillars around which food security is built.

Food security in this paper is seen as the availability in terms of quantity, appropriate amount of crops, and livestock products for use by man. Food security in this study is proxied by crop production output (CPQ) and livestock production output (LPQ) in Nigeria.

2.1.2 Climate Change

The Intergovernmental Panel on Climate Change (IPCC, 2007) opined that climate change is measurable and significant changes in weather conditions over some time, usually over decades. Climate change has become a global issue that is on the front burner of discussion by governments, academics, agriculturists, environmentalists, and society at large because of its severe consequences on the existence of man. According to Sowunmi and Akintola (2010), global warming which results mostly from human activities is the cause of climate change and poses a serious threat to agricultural productivity. Todaro and Smith (2015) see climate change as changes in nature that reduce annual rainfall, increase annual temperature, and increase drought and flooding.

For this study, climate change is defined as the emission of greenhouse gases into the atmosphere which causes alteration in the weather conditions (increased temperature, rise in sea level, flooding, drought, and variation in rainfall) in a geographical area that is capable of affecting food security. Climate change is proxied by carbon dioxide equivalent ($CO_{2\,e}$) in this study.

2.1.3 Herders-farmers conflict

Nwankwo et al. (2019) opined that herders are nomadic who move from one part of the country to another in search of greener pastures for their cattle but in the process tend to conquer rural settlements mostly farming households through the use of force and tend to live in such places permanently. According to Mufutau et al. **(**2020), most of the herders found in Nigeria are from the Fulani tribe, and in their bid to pasture, their cattle usually engage in conflict with farmers (who are engaged in either small-scale or large-scale cultivation of crops as means of livelihood) as a result of destruction crops by cattle, disagreement over grazing routes, destruction of cattle rustling, rape of female farmers, contamination of water sources by cattle, killing of cattle by farmers, among others.

Thus, this study opined that herders-farmers conflict is the violent disagreements between pastoralists who are mostly from Fulani extraction that move in large numbers towards the southern part of the country seeking greener pastures for their cattle and farmers who are mostly peasant farmers who cultivate crops on their ancestral lands for consumption or sale.

2.2 Empirical Review

2.2.1 Reviews on climate change and crop production

Eregha et al. (2014) employed the Vector Error Correction Model (VECM) to examine the effect of climate change on crop yield in Nigeria on a dataset between 1970 and 2009. Findings from the result of the study revealed that the influence of the regressors: carbon dioxide, temperature, and rainfall which proxied climate change were found to be either positive or negative depending on the type of crop, the climate change variable, and the duration of maturity of the crop. This review is limited by the duration of the study. It is not a recent study and undermines the importance of carbon dioxide equivalent in its model.

Ahmed et al. (2016) employed logit regression and correlation matrix in examining the effect of climate change on food security in Taraba State on a dataset from 1983 to 2012. Results from the findings revealed that climate change had a direct and significant effect on cassava yield in the study area. The study advocated for the provision of timely climate change information to farmers to curtail the adverse effect of climate change on crop production. Recency and limited coverage of the study area are the drawbacks of this study as compared to this present study.

Using the Vector Error Correction Model (VECM), Idumah et al. (2016) examined the influence of climate change on food production in Nigeria from 1975-2010. Findings from the result of the study revealed that rainfall positively and significantly influenced food production in the short run. But negatively influenced food production in the long run. This study is limited to the use of only the primary element of climate change, rainfall. It is also not a recent study.

Lone et al. (2017) examined climate change and its impact on crop productivity in India employing qualitative and descriptive techniques; the study revealed that climate change negatively influenced crop yield in the study area. This review neglects the effect of climate change in Nigeria. It also employed qualitative analysis as against the sophisticated quantitative analysis employed in this present study.

Moderate rainfall and temperature were found to be positively correlated to yam yield while extreme climate negatively affected production in a study carried out by Uger (2017) while examining climate variability on yam production in Benue State. The study employed a multi-linear regression model and descriptive analysis. Uger (2017) in the study reviewed above limited the study to the effect of climate change on yam production in Benue State as against the holistic approach employed by this present study.

The fully modified least square methodology was employed by Ejemeyovwi et al. (2018) to examine the relationship between carbon dioxide emission and crop production in Nigeria between 1970 and 2015. Findings from the result revealed that carbon dioxide emission positively and significantly influenced crop yield in the study area. This review is limited to one component of food production only, crop production. In addition, the study is not up to date like this present study.

Using the recursive dynamic computable general equilibrium model, Eshete et al. (2020) examined the effect of carbon dioxide emission on agricultural productivity and welfare in Ethiopia. Results from the findings of the study revealed that carbon dioxide emission is negatively influenced by crop yield in the study area. This review neglected the effects of climate change on food production in Nigeria and also focused on crop production alone.

Employing the Non-linear Auto-regressive Distributed Lag (NARDL) methodology, in examining the impact of climate change on crop production in Nigeria from 1990-2020; Alehile et al. (2022) found that in the short-run, the impact of climate change on crop production is both direct and inverse while in the long-run, climate change negatively influenced crop production. The study advocated for the provision of irrigation systems to enhance crop yield in Nigeria. Alehile et al. (2020) focused on the effects of climate change on just one component of food production, crop production to the detriment of other important ones like livestock production. The study also undermines the importance of carbon dioxide equivalent as an important element of climate change.

2.2.2 Reviews on climate change and livestock production

In the work of Cheng et al. (2022) climate change was revealed to negatively influence livestock production in the study area. Furthermore, results from the findings revealed that a bidirectional relationship exists between climate change and livestock production. Cheng et al. (2022) employed descriptive and qualitative analysis in their study. This reviewed study focused on the effects of climate change on livestock production to the detriment of the major component of food production, crop production. Also employing qualitative and descriptive statistics, FAO (2021) examined climate-smart livestock production in Asia and the Pacific region and found that climate change is inversely related to livestock production in the regions of the study. Furthermore, Grossi et al. (2019) examined the influence of livestock on climate change; Rojas-Downing et al. (2017) investigated the effect of climate change on livestock production; Baumgard et al. (2012) ascertained the impact of climate change on livestock production; and Nwosu and Ogbu (2011) examined the influence of climate change on livestock production in Nigeria. All these studies employed qualitative and descriptive methodologies and collectively asserted that climate change negatively influenced livestock production. FAO (2021), Grossi et al. (2019), Rojas-Downing et al. (2017), Baumgard et al. (2012), and Nwosu and Ogbu (2011) in their studies neglected the importance of carbon dioxide equivalent as a measure of climate change in their analysis. This present study takes care of this omission.

Employing qualitative and descriptive methodology, Easter et al. (2018), examined climate change, cattle, and the challenge of sustainability in a tele-coupled system in Africa. Results from the findings of the study opined that climate change is projected to positively influence livestock production in Africa. Increasing temperatures tend to limit the reproductive capacities of livestock and the spread of tsetse flies and trypanosomosis which affect livestock production in Africa. This reviewed study focused on the effects of climate change on livestock production in Africa using qualitative methodology as against the country-specific analysis done by this present study and the quantitative approach used for better research output.

2.2.3 Reviews on conflict and food security

Adelakun et al. (2015) investigated the socioeconomic effects of farmer-pastoralist conflict on agricultural extension service delivery in Oyo State in Nigeria. The study employed chi-square and t-test and found that farmers are the worst hit of farmer-pastoralist conflicts. The study recommended that a three-tier farmer-herdsmen conflict management committee should be set up to tackle this threat to food security. This review is limited in scope in terms of the study area, Oyo State as against the nationalistic approach employed by this present study.

Using probit regression methodology, Umeh and Chukwu (2016) examined the socioeconomic perspectives on arable crop farmer-herder conflicts in Ebonyi North Zone of Ebonyi State in Nigeria. The findings of the study revealed that both herders and farmers are negatively affected by the conflict, however, herders are the most hit by the conflict. Thus, the study recommended that peace and reconciliation meetings by the government should involve both herders and farmers for amicable resolutions. The major drawback of this review is the focus on the conflicts between herders and farmers in Ebonyi State alone.

Eneji et al. (2019) examined the effects of insecurity on agricultural productivity in Nigeria: the case study of Gombe State. The study employed the Ordinary Least Square (OLS) methodology and found that poverty and government expenditure on security have a direct relationship with agricultural GDP. While unemployment and crime rates are inversely related to agricultural GDP. The study recommended the industrialization of the agricultural sector in addition to the provision of a peaceful environment that encourages farming. A nationwide approach to the study of the effects of insecurity especially the herders-farmers conflict will be more beneficial as these conflicts are widespread across the nation.

Analyzing the impact of insecurity on agricultural growth and transformation in Nigeria (1960-2017), 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 of agriculture should be farmer-specific while adequate security must be provided to enhance agricultural output. Although the variables used in the reviewed study are relevant to this present study, the reviewed study is not up to date.

Kwaghtser (2019) investigated the impact of the conflict between farmers and herdsmen on food production in the agroecological Zone-B of Benue State, Nigeria using descriptive and inferential statistic approaches. Findings revealed a significant negative effect of the conflict on food production in the study area and recommended that the government should provide relief materials and food items to victims of this conflict. This study is limited as it has focused only on the conflict between herders and farmers in Benue State neglecting other areas of the country that are seriously affected by this conflict.

Obinna (2021) in a study, on human capital development, national security, and agricultural sector growth in Nigeria (1981-2017) found that government expenditure on security, and government expenditure on health and education positively influenced agricultural sector growth with an insignificant effect. Life expectancy is a key determinant of agricultural sector growth. The study employed the Auto-regressive Distributed Lag (ARDL) methodology and advocated for improved healthcare and the provision of adequate security for lives and properties. Obinna (2021) did not examine specifically, the effects of herders-farmers conflict on food security in Nigeria. Also, the scope of the study in terms of recency is not good enough.

Okafor and Chikalipah (2021) estimated the effect of terrorism on agricultural production in Nigeria (1971-2019). Findings revealed that terrorism is inversely and significantly related to agricultural output in Nigeria. The study employed the Ordinary Least Square (OLS) methodology and recommended that the security of farmers should be the government's top priority while encouraging herders to practice modern methods of cattle rearing. This review neglected the effect of the herders-farmers conflict on food production in Nigeria.

2.2.4 Research Gap

The novelty of this study lies in the fact that previous studies on the influence of climate change on food security in Nigeria have focused on carbon dioxide emissions due to its dominance among the greenhouse gases to the detriment of carbon dioxide equivalent which is a better measure of climate change. The accumulation of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and the fluorinated gases - hydro-fluorocarbons (HFCs), per-fluorocarbons (PFCs), sulfur-hexafluoride (SF_6), and nitrogen tri-fluoride (NF_3) in the atmosphere of a place over some time is collectively measured in a single unit by carbon dioxide equivalent (CO_{2e}). Furthermore, this study empirically and quantitatively examined the influence of climate change on crop and livestock aspects of food security using the autoregressive distributed lag methodology against the qualitative and descriptive methodologies commonly employed in investigating the effect of climate change on livestock production. Also, this study contributes to the debate on the aspect of food security that is most affected by the herders-farmers conflict in Nigeria using the Auto-Regressive Distributed Lag (ARDL) technique. Finally, this study examined the degree of correlation between climate change and the herders-farmers conflict in Nigeria.

3. METHODOLOGY

To examine the effect of climate change and herders-farmers conflict on food security in Nigeria, the Auto-Regressive Distributed Lag (ARDL) was employed after checking for long-run relationships using the Bound test. The study employed the ADF test to check for unit roots. Post-diagnostic tests were used to test for the absence of spurious estimates. Data covering the period 1983 to 2021 were sourced from the Central Bank of Nigeria's Statistical Bulletin (2022) and the World Bank Development Indicator (2022) and used for the analysis of this study. The study employed the Pearson Product Moment Correlation test to check for the degree of correlation between climate change and the herders-farmers conflict in the study area.

3.1 Theoretical Framework

3.1.1 The Neoclassical Theory of Production

The Neoclassical theory of production forms the theoretical foundation of this study. Solow (1957) opined that labour, capital, and technology are determinants of economic growth. Technology which is also known as the Solow residual is that proportion of long-term economic growth not explained by growth in labour or capital and therefore assigned primarily to exogenous technological change.

The neoclassical theory of production adopted for this study provides the technical relationship between inputs and output in the agricultural production function because it considers the influence of technological change on agricultural productivity. This theory is appropriate as population growth (PG), per capita income (PCI), carbon dioxide equivalent (CO_2e), arable land (AL), and commercial bank loans and advances in agriculture (CBLA) are all inputs in the agricultural production function. Crop production output (CPQ) and livestock production output (LPQ) are proxies for agricultural output.

3.1.2 Model Specification

This study relies on the neoclassical growth model developed by Robert Solow (1957) which is an extension of the Cobb-Douglas production function (1928). Eshete et al. (2020) modified the Solow model and specified a new version of it as we have below:

$$Y_A = A_t(L, K, l) \qquad (1)$$

Where:

Y_A = total agricultural output

K = capital

L = labour

l = land

A_t = technological progress.

Because of the peculiarity of this study, the above variables are replaced in model (1) thus:

Y_A = crop production output (CPQ) and livestock production output (LPQ)

K = per capita income (PCI), commercial bank loans and advances in agriculture (CBLA),

L = population growth (PG)

l = agricultural land (AL)

A_t = carbon dioxide equivalent (CO_2e)

The new models for this study are presented as shown in equations (2) and (3) below:

$$CPQ = \alpha_0 + \alpha_1 CO_2e + \alpha_2 AL + \alpha_3 PCI + \alpha_4 PG + \ell \qquad (2)$$

$$LPQ = \alpha_0 + \alpha_1 CO_2e + \alpha_2 AL + \alpha_3 PCI + \alpha_4 CBLA + \alpha_5 PG + \ell \qquad (3)$$

Where:
CPQ = Crop production output
LPQ = Livestock production output
CO_2e = Carbon dioxide equivalent
AL = Agricultural land
PG = Population growth
PCI = Per Capita Income
$CBLA$ = Commercial bank loans and advances in agriculture
ℓ = Random term

Enimu et al. (2019) opined that agricultural output is a function of the herders-farmers conflict (HFC) in Nigeria. Thus, models (2) and (3) can be restated to include HFC thus:

$$CPQ = \alpha_0 + \alpha_1 CO_2e + \alpha_2 HFC + \alpha_3 AL + \alpha_4 PCI + \alpha_5 PG + \ell \text{.......................................(4)}$$

$$LPQ = \alpha_0 + \alpha_1 CO_2e + \alpha_2 HFC + \alpha_3 AL + \alpha_4 PCI + \alpha_5 CBLA + \alpha_6 PG + \ell \text{.......................(5)}$$

Where:
HFC = herders-farmers conflict (Dummy variable), 0 = before the ranking of Fulani herdsmen as the fourth world's most deadly terrorist group by the Global Institute for Economics and Peace using the Global Terrorism Index (GTI), and 1 = period after the ranking.

Linearizing equations (4) and (5), we have:

$$LnCPQ = \alpha_0 + \alpha_1 LnCO_2e + \alpha_2 HFC + \alpha_3 AL + \alpha_4 LnPCI + \alpha_5 PG + \ell \text{.............................(4)}$$

$$LnLPQ = \alpha_0 + \alpha_1 LnCO_2e + \alpha_2 HFC + \alpha_3 AL + \alpha_4 LnPCI + \alpha_5 LnCBLA + \alpha_6 PG + \ell \text{........(5)}$$

Converting equations (4) and (5) into their respective conventional ARDL forms, we have:

$$\Delta CPQ_t = \pi_o + \sum_{i=j}^{n} \pi_1 \Delta CPQ_{t-i} + \sum_{i=j}^{n} \pi_2 \Delta CO_2 e_{t-i} + \sum_{i=j}^{n} \pi_3 \Delta HFC_{t-i} + \sum_{i=j}^{n} \pi_4 \Delta AL_{t-i} + \sum_{i=j}^{n} \pi_5 \Delta PCI_{t-i} + \sum_{i=j}^{n} \pi_6 \Delta PG_{t-i} + \beta_1 CPQ_{t-i} + \beta_2 CO_2 e_{t-i} + \beta_3 HFC_{t-i} + \beta_4 AL_{t-i} + \beta_5 PCI_{t-i} + \beta_6 PG_{t-i} + \upsilon_1 ECT_{t-i} + \lambda_{1t} \text{.......(6)}$$

$$\Delta LPQ_t = \pi_o + \sum_{i=j}^{n} \pi_1 \Delta LPQ_{t-i} + \sum_{i=j}^{n} \pi_2 \Delta CO_2 e_{t-i} + \sum_{i=j}^{n} \pi_3 \Delta HFC_{t-i} + \sum_{i=j}^{n} \pi_4 \Delta AL_{t-i} + \sum_{i=j}^{n} \pi_5 PCI_{t-i} + \sum_{i=j}^{n} \pi_6 \Delta CBLA_{t-i} + \sum_{i=j}^{n} \pi_7 \Delta PG_{t-i} + \beta_1 LPQ_{t-i} + \beta_2 CO_2 e_{t-i} + \beta_3 HFC_{t-i} + \beta_4 AL_{t-i} + \beta_5 PCI_{t-i} + \beta_6 CBLA_{t-i} + \beta_7 PG_{t-i} + \upsilon_1 ECT_{t-i} + \lambda_{1t} \text{..(7)}$$

Where: Δ is the differenced operator; π is the short-run parameter estimates; β is the long-run parameter estimates; π_0 is the constant term; ECT is the adjustment speed, and $\tilde{\upsilon}_1$ is the adjustment parameter.

A priori expectation: π_6 and β_6 (coefficients of CBLA in equations 7); π_5 and β_5 (coefficients of PCI in equations 6 and 7), and $\pi 4$ and $\beta 4$ (coefficients of AL in equations 6 and 7) are all expected to be greater than zero. While π_2 and β_2; π_3 and β_3 (coefficients of CO_2e and HFC respectively in equations 6 and 7) are all expected to be less than zero.

3.2 Data

3.2.1 Crop production output (CPQ): this is one of the components of agriculture used to proxy food security in Nigeria. Crop production output is the total crops produced in Nigeria on an annual basis that is measured in terms of the total monetary value (billions of naira) of the crops produced. This data was sourced from the Central Bank of Nigeria's statistical bulletin (2022).

3.2.2 Livestock production output (LPQ): this is another component of agriculture that is used to proxy food security in Nigeria. Livestock production output is the total livestock produced in Nigeria on an annual basis that is measured in terms of the total monetary value (billions of naira) of livestock produced. This data was sourced from the Central Bank of Nigeria's statistical bulletin (2022).

3.2.3 Carbon dioxide equivalent (CO_2e): the accumulation of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and the fluorinated gases - hydro-fluorocarbons (HFCs), per-fluorocarbons (PFCs), sulfur-hexafluoride (SF_6), and nitrogen tri-fluoride (NF_3) in the atmosphere of a place (Nigeria in this case) over some time is collectively measured in a single unit by carbon dioxide equivalent ($CO_{2\ e}$). Carbon dioxide equivalent ($CO_{2\ e}$) is a better measure of climate change as compared to carbon dioxide (CO_2) because it is all-encompassing. Carbon dioxide equivalent ($CO_{2\ e}$) contains carbon dioxide (CO_2) together with methane (CH_4) and nitrous oxide (N_2O) which have higher Global Warming Potentials (GWPs) and does more damage to the ozone layer than carbon dioxide (CO_2). Methane (CH_4) and nitrous oxide (N_2O) also stay longer in the atmosphere thereby causing more harm. Carbon dioxide equivalent ($CO_{2\ e}$) is measured in kilotonnes. It was sourced from the World Bank Development Indicators (WDI, 2022).

3.2.4 Population growth (PG): this is the annual growth rate of the population of the country. It is measured in percentages and it was sourced from the World Bank Development Indicators (WDI, 2022).

3.2.5 Per capita income (PCI): This is the gross national income divided by the midyear population of Nigeria. Per capita income is measured in billions of naira. It was sourced from the World Bank Development Indicators (WDI, 2022).

3.2.6 Arable land (AL): this is the portion of the total land area in the country that supports agricultural activities. Arable land is measured as the percentage of total land area in the country. It was sourced from the World Bank Development Indicators (WDI, 2022).

3.2.7 Commercial bank loan and advances in agriculture (CBLA): this is the loan made available to farmers in the country by the commercial banks operating in the country to support the agricultural sector. This data was sourced from the Central Bank of Nigeria's statistical bulletin (2022) and it is measured in billions of naira.

4. RESULTS AND DISCUSSION

Table 1: Descriptive Statistics

	CPQ	LPQ	CO_2e	PG	PCI	AL	CBLA
Mean	7757.740	728.4470	224010.3	2.575418	1803.854	71.53662	202.4563
Maximum	16920.52	1240.220	349873.3	2.680930	2616.773	76.43350	1457.820
Minimum	1759.115	393.1310	132908.9	2.488792	1297.579	53.46355	0.940400
Jarque-Bera	4.230193	4.579007	0.525166	3.118423	4.937957	44.41869	71.47084
Probability	0.120622	0.101317	0.769063	0.210302	0.084671	0.000000	0.000000
Observations	39	39	39	39	39	39	39

Source: Authors' computation from Eviews 10.

Table 1 revealed that between 1983 and 2021, crop production output (CPQ), livestock production output (LPQ), carbon dioxide equivalent (CO_2e), population growth (PG), per capita income (PCI), arable land (AL), and commercial bank loan and advances in agriculture (CBLA) averaged ₦7757.740 billion, ₦728.4470 billion, 224010.3 kilotonnes of CO_2 equivalent, 2.58%, ₦1803.854 billion, 71.54%, and ₦202.4563 billion respectively. The highest values of CPQ, LPQ, CO_2e, PG, PCI, AL, and CBLA within the period of the study stood at ₦16920.52 billion, ₦1240.220 billion, 349873.3 kilotonnes of CO_2 equivalent, 2.68%, ₦2616.773 billion, 76.43% and ₦1457.820 billion respectively. While the lowest values of CPQ, LPQ, CO_2, PG, PCI, AL, and CBLA stood at ₦1759.115 billion, ₦393.1310 billion, 132908.9 kilotonnes of CO_2 equivalent, 2.49%, ₦1297.579 billion, 53.46% and ₦0.9440400 billion respectively. The high values of the Jarque-Bera test indicate that the observations are not normally distributed, hence, the need to proceed by testing for unit root is presented in Table 2.

Table 2: Summary of Unit Root Test

Variables	ADF t-test @ levels	Mackinnon Critical Value @ 5%	ADF t-test @ first difference	Mackinnon Critical Value @ 5%	Order of Integration
CPQ	-0.766393	-2.941145	-6.290200	-2.943427	1(1)
LPQ	0.084348	-2.943427	-3.785490	-2.943427	1(1)
CO_2e	-0.730081	-2.941145	-4.607303	-2.943427	1(1)
PG	-4.980896	-2.963972			1(0)
PCI	-0.479534	-2.943427	-5.434066	-2.943427	1(1)
AL	1.218800	-2.967767	-4.718203	-2.943427	1(1)
CBLA	-0.798487	-2.941145	-6.957365	-2.943427	1(1)

Note: if t*≤ADF (Critical Values) = Unit root does not exist.

Source: Authors' computation from Eviews 10.

Table 2 revealed that all the variables of interest used in this research are integrated of order one I(1) except for population growth (PG) which is integrated of order zero I(0). The Auto-Regressive Distributed Lag (ARDL) methodology thus becomes appropriate for further analysis. Table 3 presents the optimal lag selection criteria for models one and two.

Table 3: Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
Model I						
0	155.2414	NA	1.56e-11	-7.854808	-7.596242	-7.762812
1	415.2385	424.2059*	1.22e-16*	-19.64413*	-17.83417*	-19.00016*
Model II						
0	207.8600	NA	6.05e-14	-10.57158	-10.26992	-10.46425
1	509.8538	476.8324*	1.04e-19*	-23.88704*	-21.47376*	-23.02842*

Note: * indicate lag order selection criterion. The Akaike Information Criterion (AIC) was utilized in this study.

Source: Authors' computation from E-views 10.

Table 3 of the lag order selection criteria suggests that lag 1 is optimal for both models. Hence, lag 1 is used in the ARDL long run and bound tests for models one and two.

Table 4: ARDL Bounds Test

Test Statistics	Value	Signif.	I(0)	I(1)
Model I				
Dependent variable: D(LNCPQ)				
Selected Model: ARDL (1,1,0,0,0,1)				
F-Statistic	6.737155	10%	2.08	3

K	5	5%	2.39	3.38
Model II				
Dependent variable: D(LNLPQ)				
Selected Model: ARDL (1, 0, 0, 1, 0, 0, 1)				
Test Statistics	**Value**	**Signif.**	**I(0)**	**I(1)**
F-Statistic	20.04267	10%	1.99	2.94
K	6	5%	2.27	3.28

Source: Authors' computation from E-views 10.

The ARDL bound tests for models one and two are presented in Table 4. The result revealed the presence of long-run relationships between the dependent variable and the independent variables in models one and two as evident in the F statistics values of 6.737155 and 20.04267 respectively. The F statistics values are greater than both the lower bounds I(0) and upper bounds I(1) at a 5% level of significance. Thus, the ARDL short-run and long-run forms of the models are estimated. Tables 7 and 8 present the short-run and long-run ARDL estimation of models one and two respectively.

Table 7: ARDL Short-run and Long-run Estimation for Model I

Model I				
Dependent variable: D(LNCPQ)			**Sample:** 1983-2021	
Selected model: ARDL (1, 1, 0, 0, 0, 1)			**Included observation:** 38	
ARDL Short-run model				
Variable	**Coefficient**	**Std. Error**	**T-Statistics**	**Prob.**
C	1.438636	1.184294	1.214762	0.2343
LNCO2E(-1)	-0.773571	0.288576	-2.680651	0.0120
HFC**	-0.026314	0.023764	-1.107307	0.2773
AL**	0.018913	0.004490	4.212192	0.0002
LNPCI**	1.912612	0.410468	4.659592	0.0001
PG(-1)	-1.214714	0.306407	-3.964383	0.0004
ARDL Long-run model				
LNCO2E	-1.693206	0.698883	-2.422732	0.0219
HFC	-0.057596	0.053315	-1.080299	0.2889
AL	0.041397	0.008333	4.967717	0.0000
LNPCI	4.186360	0.692530	6.045020	0.0000
PG	-2.658788	0.711640	-3.736143	0.0008
C	3.148911	2.850245	1.104786	0.2783
ECM	-0.456868	0.060558	-7.544358	0.0000
R-squared: 0.534137		**Adjusted R-squared: 0.507517**	**Durbin Watson Stat:** 2.387039	

Source: Authors' extraction from Eviews 10.

Table 7 revealed that carbon dioxide equivalent (CO_2e) in the short-run negatively (-0.773571) influenced crop yield in the study area. The negative effect of carbon dioxide equivalent (CO_2e) is revealed to be significant (0.0120). This result agrees with the a priori and the works of Eshete et al. (2020); and Lone et al. (2017) but disagrees with the works of Ejemeyovwi et al. (2018); and Ahmed et al. (2016). Furthermore, in the short-run; herders-farmers conflict (HFC) negatively (-0.026314) influenced crop yield. This result agrees with the a priori and the work of Tersoo and Ogochukwu (2014). The effect of carbon dioxide equivalent (CO_2e) on crop yield maintained its negative (-1.693206) and significant (0.0219) influence in the long run, while the effect of herders-farmers conflict (HFC) on crop yield remained negative (-0.057596) and

insignificant (0.2889).
Furthermore, the ECM which represents the speed of adjustment to equilibrium revealed that model one with a value of -0.456868 is negative and significant as expected. The adjusted R-squared value in model one suggests that approximately 51% of the variations in crop production output (CPQ) are caused by variations in the independent variables while the remaining 49% of variations are caused by other variables not included in the model.

Table 8: ARDL Short-run and Long-run Estimation for Model II

Model II				
Dependent variable: D(LNLPQ)			**Sample:** 1983-2021	
Selected model: ARDL(1, 0, 0, 1, 0, 0, 1)			**Included observation:** 38	
ARDL Short-run model				
Variable	**Coefficient**	**Std. Error**	**T-Statistics**	**Prob.**
C	0.198458	0.275596	0.720103	0.4774
LNLPQ(-1)*	-0.184163	0.063694	-2.891393	0.0073
LNCO2E**	-0.085333	0.070812	-1.205063	0.2383
HFC**	0.001797	0.006575	0.273383	0.7866
LNPCI**	0.362995	0.104441	3.475587	0.0017
D(AL)	-0.005903	0.002235	-2.641455	0.0134
ARDL Long-run model				
LNCO2E	-0.463353	0.399305	-1.160399	0.2557
HFC	0.009760	0.034709	0.281190	0.7806
AL	0.000453	0.006722	0.067354	0.9468
LNPCI	1.971048	0.665341	2.962463	0.0062
LNCBLA	0.031441	0.050920	0.617462	0.5419
PG	-0.843467	0.544511	-1.549035	0.1326
C	1.077618	1.475443	0.730369	0.4712
ECM	-0.184163	0.013008	-14.15721	0.0000
R-squared: 0.677490		**Adjusted R-squared:** 0.659061	**Durbin Watson Stat:** 1.895965	

Source: Authors' extraction from Eviews 10.

Table 8 revealed that carbon dioxide equivalent (CO_2e) negatively (-0.085333, -0.463353) and insignificantly (0.2383, 0.2557) influenced livestock production (LPQ) both in the short run and in the long run respectively. This result agrees with the a priori and the works of Cheng et al. (2022); FAO (2021); Grossi et al. (2019); Rojas-Downing et al. (2017); Baumgard et al. (2012); and, Nwosu and Ogbu (2011) as regards the direction of the relationship between carbon dioxide equivalent (CO_2e) and livestock production. However, this result disagrees with the works of Eshete et al. (2020) and Easter et al. (2018). Herders-farmers conflict (HFC) positively (0.001797, 0.009760) but insignificantly (0.7866, 0.7806) influenced livestock production both in the short run and in the long run respectively. This may not be unconnected with the continued occupation and grazing of cattle by the herders on the farms in villages and towns where farmers have fled their homes and taken refuge in safer places. As such, livestock production tends to benefit from this conflict to the detriment of crop production as earlier discovered by Adelagun et al. (2015).
Furthermore, the ECM which represents the speed of adjustment to equilibrium revealed that model two with a value of -0.184163 is negative and significant as expected. The adjusted R-squared value in model two suggests that approximately 66% of the changes in livestock production output (LPQ) are caused by variations in the independent variables employed in the model while the remaining 34% of variations in the dependent variable are caused by other factors not included in the model.

Table 9: Correlation Analysis

		$LnCO_2e$	HFC
$LNCO_2e$	Pearson Correlation	1	0.679**
	Sig. (2-tailed)		0.000
	N	39	39
HFC	Pearson Correlation	0.679**	1
	Sig. (2-tailed)	0.000	
	N	39	39

****.Correlation is significant at the 0.01 level (2-tailed).**
Source: Authors' extraction from SPSS 16.

Table 9 presents the result of the Pearson correlation test. The result revealed that a high correlation exists between carbon dioxide equivalent (CO_2e) and herders-farmers conflict within the period of the study. This result implies that climate change is highly linked to the herders-farmers conflict experienced in Nigeria during the period of this study.

Table 10: Post-Diagnostic Estimates for model 1

Breusch-Pagan-Godfrey Heteroskedasticity Test			
F-statistic	2.232527	Prob. F(8,29)	0.0543
Obs*R-squared	14.48325	Prob.Chi-square(8)	0.0700
Breusch-Godfrey Serial Correlation LM Test			
F-statistic	1.465115	Prob. F(1,28)	0.2362
Obs*R-squared	1.889501	Prob.Chi-square(1)	0.1693

Source: Authors' extraction from Eviews 10.

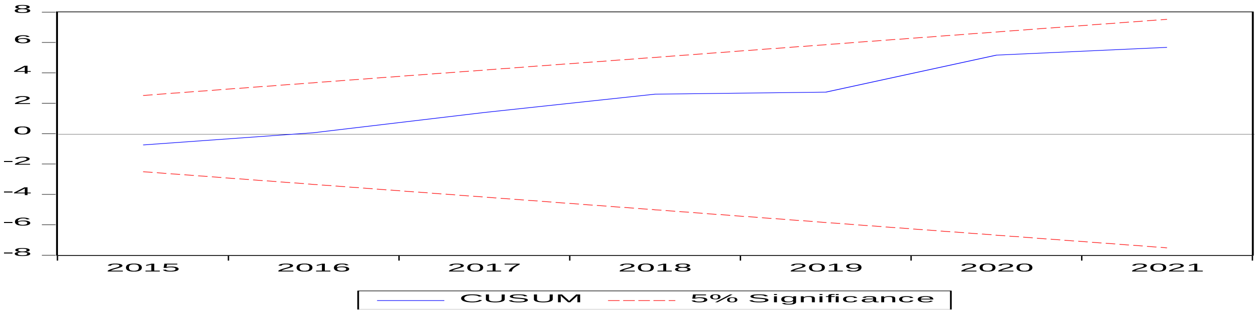
Table 11: Post-Diagnostic Estimates for Model 2

Breusch-Pagan-Godfrey Heteroskedasticity Test			
F-statistic	1.398194	Prob. F(9,28)	0.2360
Obs*R-squared	11.78261	Prob.Chi-square(9)	0.2258
Breusch-Godfrey Serial Correlation LM Test			
F-statistic	0.073281	Prob. F(1,27)	0.7887
Obs*R-squared	0.102857	Prob.Chi-square(1)	0.7484

Source: Authors' extraction from Eviews 10.

The Breusch-Pagan-Godfrey heteroskedasticity and the Breusch-Godfrey serial correlation LM tests for models one and two are presented in Tables 10 and 11 respectively. Results from the Tables revealed the presence of constant variance and the absence of autocorrelation in the variables used for the analysis of this study.

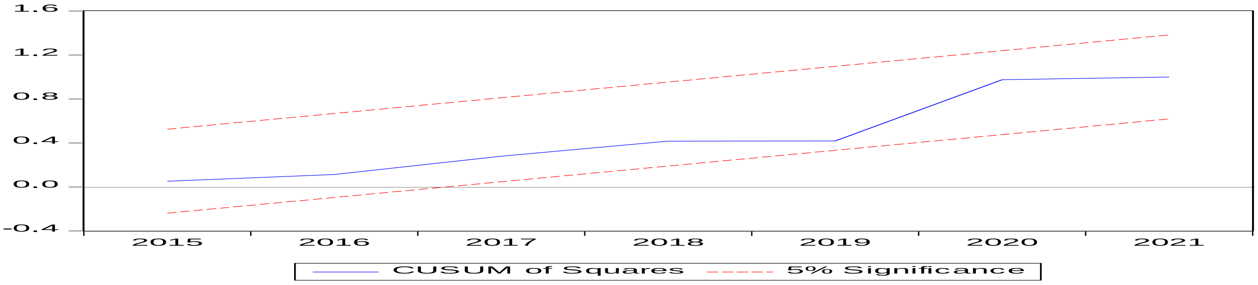
Figure 1: CUSUM Stability for model 1



Source:

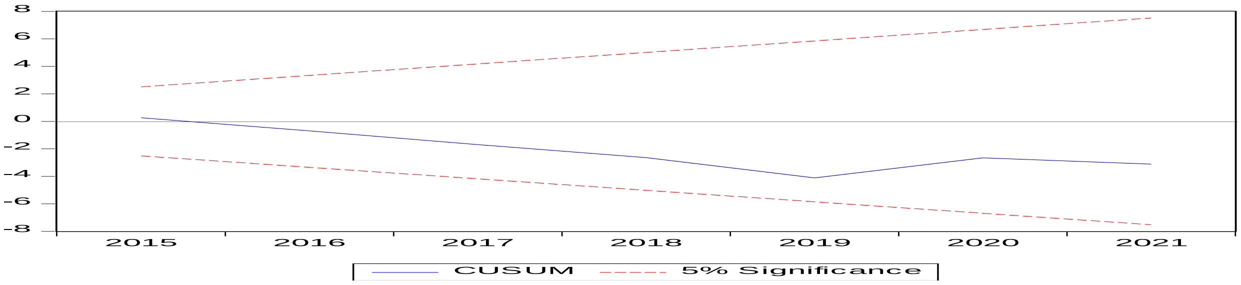
Eviews 10 Output.

Figure 2: CUSUM of Squares Stability for model 1



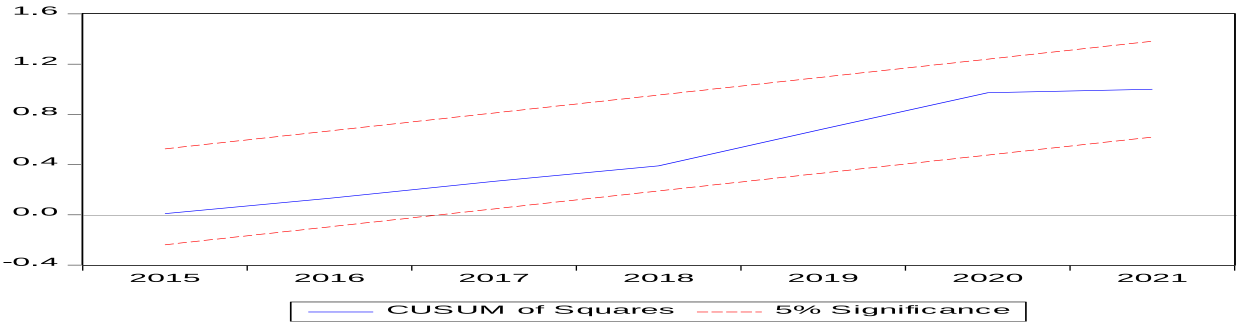
Source: Eviews 10 Output.

Figure 3: CUSUM Stability for model 2



Source: Eviews 10 Output.

Figure 4: CUSUM of Squares Stability for Model 2



Source: Eviews 10 Output.

The CUSUM stability diagnostics for models one and two are presented in Figures 1 and 3 respectively. Furthermore, the CUSUM of squares stability diagnostics for models one and two are presented in Figures 2 and 4 respectively. The movement of the blue lines within the boundaries of the red lines depicts the stability and appropriateness of the variables included in the models of this study.

5. CONCLUSION AND RECOMMENDATIONS

This study employed the Pearson Product Moment Correlation and the Auto-Regressive Distributed Lag (ARDL) methodology in examining the influence of climate change and herders-farmers conflict on food security in Nigeria between 1983 and 2021. Climate change proxied by carbon dioxide equivalent (CO_2e) tends to negatively and significantly influence food security proxied by crop production both in the short run and long run. Climate change is inversely related to livestock production. However, its impact is insignificant. Furthermore, the herders-farmers conflict negatively influenced crop production both in the short-run and long-run but its impact remained insignificant. Also, a positive relationship exists between herders-farmers conflict and livestock production both in the short run and in the long run. Finally, climate change is highly correlated to the herders-farmers conflict in Nigeria within the period of the study. The study advocated for the practice of climate-smart agriculture in addition to the provision and use of improved varieties of seeds that can withstand the negative effects of climate change. Furthermore, irrigation farming should be encouraged to make the availability of some crops all year round possible. Also, the free-range method of cattle rearing should be reconsidered and appropriate measures taken to ranch cattle since the herders-farmers conflict favour livestock production to the detriment of crop production in Nigeria. Finally, the government should make concerted efforts to find the actual cause of the conflict between herders and farmers and resolve it to guarantee food security.

6. LIMITATIONS OF THE STUDY AND SUGGESTIONS FOR FUTURE RESEARCH

In the formulation of the models of this study, variables like modern farming equipment, fertilizer use, and irrigation systems were not captured due to the interest of the researchers. Thus, this study suggests that future studies should consider the mentioned variables as they influence agricultural productivity. Furthermore, since this study is limited to Nigeria, the generalization of the findings may not be accurate. Thus, researchers should consider replicating the study in other less developed countries especially African nations where the effects of climate change and insecurity are becoming serious threats to economic development.

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