

Alehile, Kehinde Samuel

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## Climate Change Effects on Employment in the Nigeria's Agricultural Sector

Kehinde Samuel ALEHILE 

*Department of Economics, Faculty of Social Sciences  
Kogi State University, Anyigba 270109, Nigeria  
[alehile.ks@ksu.edu.ng](mailto:alehile.ks@ksu.edu.ng)*

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Climate change poses mounting risks to agricultural development and rural livelihoods in Nigeria. This study investigates the impacts of climate change on agricultural sector employment in Nigeria. Agriculture provides income and sustenance for much of Nigeria's rural population. However, smallholder rain-fed farming predominates, with minimal resilience to climate shifts. Historical data reveal rising temperatures and declining, erratic rainfall across Nigeria's agro-ecological zones since the 1970s. Crop modeling predicts further climate changes will reduce yields of key staple crops. This threatens the viability of smallholder agriculture and risks widespread job losses. The study adopts a nonlinear autoregressive distributed lag (NARDL) modeling approach to evaluate climate change effects on agricultural sector employment in Nigeria from 1990 to 2020. Findings reveal reduced rainfall initially raises employment, as farming requires more labor in dry conditions. However, protracted droughts significantly reduce agricultural jobs. Increased temperatures consistently lower farm employment through reduced yields and incomes. Based on these findings, the study recommends that adaptive strategies are urgently needed to build resilience, promote climate-smart agriculture, and safeguard rural livelihoods.

**Keywords:** Climate change; agricultural employment; rainfall; temperature; Nigeria.

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### 1. Introduction

Climate change represents a serious threat to global food security and sustainable development in the 21st Century. According to the latest assessment reports by the Intergovernmental Panel on Climate Change (IPCC), increasing concentrations of greenhouse gases are expected to raise average temperatures, alter precipitation patterns, and trigger more frequent and intense extreme weather events across the world (IPCC, 2014). Agricultural

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systems are especially vulnerable to climate variations as crop and livestock production relies heavily on favorable temperature, rainfall, and climate conditions. Developing countries dependent on agriculture face heightened risks to rural livelihoods, poverty reduction, and economic growth if climate change severely disrupts the agricultural sector (Apata and Gabriel, 2012).

Nigeria, despite its oil resources, remains fundamentally an agrarian economy. Agriculture accounts for approximately 22% of its national GDP and provides employment to about 30% of the workforce, especially in rural areas (NBS, 2020). Smallholder rain-fed farming dominates the sector, with limited mechanization and low resilience to climate fluctuations. Key crops include maize, rice, sorghum, millet, cassava, yam, and cash crops like cocoa, oil palm, and rubber. Livestock farming also constitutes an important agricultural activity (FMARD, 2016). However, empirical studies demonstrate that Nigerian agriculture is highly vulnerable to projected climate shifts (Adejuwon, 2004; Obioha, 2015; Adejuwon *et al.*, 2014). Changes in temperature, precipitation, extreme weather frequency, and growing season length can negatively impact crop and livestock yields.

Climate change poses a major threat to agricultural development and food security in Nigeria in the 21st Century (IPCC, 2014). Rising temperatures, changing rainfall patterns, and more frequent extreme weather events will likely reduce crop yields, farm profits, and agricultural employment (Amjad *et al.*, 2018; Knox *et al.*, 2012). Higher temperatures, reduced rainfall, and increased climate extremes can lower crop yields by disrupting growth cycles, increasing water stress, and enabling pests (Amjad *et al.*, 2018; Fatuase *et al.*, 2018). Cereal crop yields in sub-Saharan Africa are projected to decline by 10–20% on average by mid-century under severe climate change (Knox *et al.*, 2012; Jalloh *et al.*, 2017), in northern Nigeria, millet and sorghum yields could fall by 13–20% by 2080.

Agriculture sector employs about 30% of Nigeria's workforce, so climate impacts threaten rural livelihoods (NBS, 2020; Komolafe *et al.*, 2015). Historical meteorological data show rising temperatures and declining rainfall in Nigeria's key farming zones since the 1970s (Adeyemi *et al.*, 2015; Ifeanyi-Obi *et al.*, 2016). Temperatures have increased by 0.2–2.7°C across various agro-ecological zones over the past three decades (Olaniyi *et al.*, 2016; Abiodun and Lawal, 2016). Rainfall has declined by 2–8% in northern Nigeria and become more variable in the south (Oyekale, 2015; Obioha, 2015). Climate models predict these trends will continue through the 21st Century. Reduced agricultural productivity threatens the viability of smallholder farming in Nigeria. With poorer harvests, small farms are compelled to lay off workers, rely on family labor, or exit farming (Adelakun *et al.*, 2015; Lawal *et al.*, 2016). Modeling studies estimate climate change could eliminate 40–45% of unskilled agricultural jobs in northern Nigeria by 2050 (Ahmed and Schmitz, 2015).

While many studies analyze the biophysical effects of climate change on Nigerian agriculture, there is limited research on the socioeconomic impacts, especially regarding employment and livelihoods of farm households. With agriculture central to rural income and employment generation, climate change may substantially alter the quantity and quality of agricultural jobs available (FAO, 2018). Reduced farm productivity and profitability could undermine livelihood viability, particularly for marginal and smallholder

farmers with limited capital reserves or alternate income sources. This raises concerns over potential declines in agricultural employment, increased rural–urban migration, and exacerbated poverty levels (Idowu *et al.*, 2011). Therefore, this study aims to address this knowledge gap by estimating the effect climate change has on agricultural sector's employment.

## **2. Literature Review**

The literature review section explores the interconnected aspects of climate change and agricultural sector employment in Nigeria. Notably, climate change results from both natural and human-induced factors, with fossil fuel combustion and deforestation contributing significantly to the greenhouse effect. In Nigeria, the agricultural sector is a cornerstone of the economy, significantly contributing to the GDP growth and providing livelihoods to a substantial portion of the population, mainly smallholder farmers in rural areas. However, this sector faces complex challenges, including limited access to modern farming techniques, inadequate infrastructure, and the substantial impact of climate change, which affects agricultural employment. Consequently, this literature review synthesizes empirical research on the climate change-agricultural employment relationship in Nigeria, exploring impacts, adaptations, and potential solutions.

### **2.1. Conceptual literature**

The conceptual literature review provides the theoretical and foundational concepts that underpin the exploration of climate change and its impact on agricultural sector employment in Nigeria. Understanding the theoretical underpinnings is essential for interpreting empirical research findings, as it offers insights into the key variables, relationships, and theoretical models that guide the investigation.

#### **2.1.1. Climate change**

According to the United Nations Framework Convention on Climate Change, the term is sometimes used to refer especially to climate change brought on by human activity rather than by natural processes on earth (UNFCCC, 2002). Climate change is a long-term change in the planet's or a particular location's weather patterns. Changes in characteristics of typical weather, such as temperature, wind patterns, and precipitation, are used to gauge the shift. While in the context of environmental policy, the phrase “climate change” has come to mean “anthropogenic global warming”, which is the increase in average surface temperature, it might also refer to a change in average weather conditions or in the distribution of weather around normal conditions (IPCC, 2007).

Climate change includes a variety of natural factors, including fluctuations in the quantity of solar radiation that enters the planet's system, the location of the earth in relation to the sun, the position of the continents in relation to the equator, and even whether the continents are contiguous or not. There are more greenhouse gases in the atmosphere as a result of human activity. As the atmosphere becomes covered with

greenhouse gases, it is as if another blanket is thrown on the earth. The primary human-made source of greenhouse gases is the combustion of fossil fuels and biomass (living matter). Additional human activities that affect the climate of the planet include air pollution, urbanization, and deforestation (the loss of trees) (Dana, 2008).

### *2.1.2. Agricultural sector employment*

The concept of Agricultural Sector Employment in Nigeria refers to the vital role that agriculture plays in providing livelihoods and employment opportunities to a significant portion of the Nigerian population. This sector encompasses a wide range of activities related to farming, livestock rearing, and agribusiness. In Nigeria, agriculture is not only a source of income but also a means of food production and sustenance for many rural and urban households. It forms the backbone of the economy, contributing substantially to the nation's GDP.

Historically, the agricultural sector has been a primary source of employment in Nigeria, engaging millions of individuals across the country. Smallholder farmers, particularly in rural areas, make up a significant proportion of the agricultural workforce. However, it is important to note that this sector faces various challenges, including climate change, inadequate access to modern farming techniques, and infrastructure limitations. These issues impact productivity and the livelihoods of those dependent on agricultural employment.

Efforts to enhance agricultural sector employment in Nigeria often revolve around modernizing farming practices, improving access to credit and markets, and implementing policies that promote sustainable agriculture. Additionally, addressing the impact of climate change on agriculture is of utmost importance, as it can have profound consequences on the livelihoods of those employed in this sector. Therefore, understanding the dynamics of agricultural employment in Nigeria is essential for both policymakers and researchers seeking to bolster rural development and economic growth.

### *2.1.3. Climate change and agricultural sector employment*

Climate change is expected to have a significant impact on agricultural sector employment in Nigeria, which employs over 70% of the population. The sector is highly vulnerable to climate change, as it is heavily dependent on weather conditions and climate-sensitive resources, such as water and land. One of the channels through which climate change is expected to impact agricultural sector employment in Nigeria is through changes in crop yields. Climate change is expected to lead to more extreme weather events in Nigeria, such as droughts and floods, which can damage crops and reduce yields. According to a study by the International Food Policy Research Institute, climate change could lead to a decrease in maize yields of up to 20% in Nigeria by 2050. A study by Akinbobola *et al.* (2015) found that climate change could lead to a decrease in cassava yields of up to 10% in Nigeria by 2050. In a study by the Federal University of Agriculture, Abeokuta found that climate change could lead to a decrease in cocoa yields of up to 15% in Nigeria by 2050. Reduced yields can lead to lower demand for agricultural labor, as farmers will need fewer workers to produce the same amount of food. Also, Adefolalu (2017) and

Ogunlesi and Ajibola (2020) indicate potential declines in crop yields due to erratic rainfall, prolonged droughts, and increased temperatures. These yield changes may necessitate alterations in labor demand within the sector, potentially leading to job losses or shifts in employment patterns.

Also, changes in climate patterns might exacerbate resource scarcity, such as water shortages or soil degradation, leading to increased input costs for farmers. Studies by Ogunlari and Awokuse (2018) and Olayide (2014) emphasize how elevated input costs can influence labor demand due to changes in agricultural practices or technology adoption, potentially affecting employment levels in the sector.

Another channel through which climate change is expected to impact agricultural sector employment in Nigeria is through changes in land use. Climate change is expected to lead to changes in temperature and precipitation patterns in Nigeria, which could make some areas less suitable for agriculture. As a result, farmers may be forced to abandon some land or switch to crops that are more tolerant to climate change. This could lead to job losses in the agricultural sector, as fewer workers will be needed to farm less land.

Finally, climate change is also expected to impact agricultural sector employment in Nigeria through changes in labor productivity. Climate change could lead to increased heat stress and other health problems for agricultural workers in Nigeria, which could reduce their productivity. Additionally, climate change could damage agricultural infrastructure in Nigeria, such as irrigation systems and roads, which could also reduce labor productivity. The impact of climate change on agricultural sector employment is expected to be particularly severe in rural Nigeria, where the agricultural sector is the main source of employment. As a result, climate change could lead to widespread unemployment and poverty in rural Nigeria.

## **2.2. Empirical literature review**

To evaluate the influence of climate change on different economic factors, a number of economic research studies on the subject have been conducted. Climate change is a fact, as evidenced by the numerous effects of the shift, including an increase in temperature, rainfall, sea level rise, desertification, flooding, and drought, among these are Idumah *et al.* (2016) used secondary data from a food and agricultural organization database to evaluate the impact of climate change on food production in Nigeria. The study, which relied on a vector error correction model, discovered a long-term connection between climate change and food production as well as a positive association between rainfall and food output. With time series data from 1985 to 2016, Matthew *et al.* (2019) investigated the impact of greenhouse gas emissions on health outcomes in Nigeria. They used an auto-regressive distributed lag model with temperature and rainfall as the variables for rainfall. According to the study, an increase in greenhouse gases lowers death rates and life expectancy. A multinomial logit model encompassing the years 1972–2012 was used by Esiobu and Onubuogu (2014) to evaluate the trends, patterns, and alternatives for livestock producers in Imo state to adapt to climate change. Both primary and secondary data were used. Secondary data were gathered from agro-meteorological stations and the national root crops research institution Umudike, Abia state, while primary data were gathered

by administering questionnaires to a sample size of 60 livestock farmer families. The data were analyzed using simple percentages and chi-square. According to the study, farmers' socioeconomic characteristics significantly influence their ability to adapt to climate change.

Akinbobola *et al.* (2015) used an ordinary least square (OLS) estimate approach to assess the effect of climate change on the composition of agricultural production in Nigeria between 1981 and 2011, and discovered that all but fisheries are positively and significantly impacted by climate change. Additionally, Ayinde *et al.* (2010) used regression analysis, descriptive statistics, and the Granger causality test to conduct an empirical analysis of agricultural production and climate change in Nigeria from 1987 to 2005. They discovered that rainfall exhibits variability and that there is a causal relationship between climate change and agricultural output.

Ayinde *et al.* (2011) used a co-integration model technique with time series data covering from 1980 to 2005 to evaluate the impact of climate change on agricultural productivity in Nigeria. The study discovered that rainfall varied over the study period and that temperature fluctuations had a detrimental impact on agricultural output while rainfall had a favorable impact. With data covering the years from 1985 to 2010, Akanbi *et al.* (2014) examined the interactions between climatic change, human capital development, and economic growth in Nigeria. The Cobb–Douglas production function was expanded in this study to incorporate capital stock and Carbon (IV) Oxide (CO<sub>2</sub>) emission as production function inputs. The study used OLS for the model's estimate and discovered that climate change placed restrictions on human capital development and had a detrimental effect on Nigeria's economic growth.

Oduyoye-Ejumedia and Ejumedia (2019) evaluated the effects of climate change on productivity in sub-Saharan Africa from 1986 to 2016. The study used the completely modified OLSs cointegration technique and the Johansen and Fisher Panel cointegration test. The research found that climate change has a detrimental influence on overall production as measured by yearly temperature and precipitation. Ashrafun *et al.* (2018) assessed the impact of climate change on rice farmers and market in Bangladesh using a partial-equilibrium multi-region farm household model to quantify the impacts of climate change on land consumption, income, prices production, and farmers' welfare. The results indicated that the decline in production in the coastal and northern regions offsets the production increase in the central and eastern regions and the simulation predicted that rice production in Bangladesh will decrease by about 2%.

Mano and Nhemachena (2007) used the Ricardian approach to examine the economic impact of climate change on agriculture in Zimbabwe. Using multiple regression analysis, net farm revenue is regressed against various climate, soil, hydrological, and socio-economic variables to help determine the factors that influence variability in net farm revenues. The study is based on the data from a survey of 700 smallholder farming households interviewed across the country. Empirical results from the study showed that climatic variables (temperature and precipitation) have significant effects on net farm revenues in Zimbabwe, and that net farm revenues are affected negatively by increases in temperature and positively by increases in precipitation.

Ochuodho *et al.* (2012) investigated regional economic impact of climate change and adaptation in the Canadian forest with the aid of a Computable General Equilibrium model.

The model considered 16 impact scenarios. The findings of the study revealed that the physical and economic impact of climate change in Canadian forests may be substantial and will not be distributed equally across Canada's regions. For instance, without adaptation, Manitoba, Saskatchewan and the Territories' forestry and logging sector may be hardest hit, losing over 30% of its output value, thereby reducing output and GDP in other sectors by over 18%. On the other hand, provinces such as Quebec and to a lesser extent Ontario could gain up to 2% in their forestry and logging and other sector output and GDP. With adaptation, the negative impact is reduced and the positive impact is increased in all regions. In this case, Atlantic Canada in particular could realize output and GDP gains, at up to 2% compared to a no climate change, no adaptation scenario.

Takaaki (2016) investigated rainfall variability and macroeconomic performance in India within the period of 1952–2013 using an integrated assessment model which incorporates economy and climate change modules. The study found that rainfall variability impacts non-agricultural sectors through its impact on agricultural sector. Kumar (2012) analyzed the impact of climate change and economic food waste in the United States using loss-adjusted national food availability data for 134 food commodities, it calculated the greenhouse gas emissions due to wasted food using life cycle assessment and the economic cost of the waste using retail prices. The study adopted the panel regression model. The analysis showed that avoidable food waste in the US exceeds 55 million metric tons per year, nearly 29% of annual production. This waste produces life-cycle greenhouse gas emissions of at least 113 million metric tons of CO<sub>2</sub> annually, equivalent to 2% of national emissions, and costs \$198 billion.

Mark *et al.* (2015) carried out an economy-wide impact assessment of climate change on Philippine agriculture using a dynamic computable general equilibrium (DCGE) model of Philippines and found that global climate change has adverse effects on crop yield resulting in higher commodity prices and that climate change reduces the long-time economic growth of Philippines by 0.02% per year which equates to 3.8% reduction in GDP by 2050. Wim (2011) argued that the costs implied by climate change will be incurred because countries and entrepreneurs need to shift their firms onto a different production technology frontier thereby changing the way goods are produced. Investment in new techniques processes as well as shifts to lower carbon energy sources is required and this will result in more costly production, at least over the medium term.

Also, Asuamah (2016) examined the impacts of climate change and globalization on the manufacturing sector of Ghana between 1961 and 2013 using the OLS, Johansen cointegration test, and Granger causality test and found that there is a bi-directional causality between climate change and manufacturing and also that there is a long-run relationship among the variables of the model. This means that there is a feedback between climate change and the manufacturing sector. The study also found that climate change negatively impacted manufacturing sector and that the impact is permanent.

Akintoye and Adagunodo (2019) carried out a comprehensive study using multiple regression econometric modeling, surveys, and agricultural data to assess climate change adaptation strategies among smallholder farmers in Nigeria. Their research, spanning from 1995 to 2018, examined the adoption of climate-resilient practices, such as drought-resistant



crop varieties and efficient irrigation methods. The findings highlighted the importance of these strategies in enhancing agricultural employment and food security in a changing climate. Various studies have extensively investigated the anticipated impacts of climate change on agricultural employment across diverse regions and countries. Deressa *et al.* (2009) conducted an evaluation in Ethiopia from 1995 to 2005, utilizing OLS regression on household survey data, indicating that climate change is poised to reduce farm income and employment, particularly affecting the arid and semi-arid zones. Similarly, Mubaya *et al.* (2012) focused on Tanzania's agricultural employment dynamics from 2000 to 2010, employing OLS regression on household survey data, foreseeing a reduction in agricultural employment, especially in the northern and central regions. Seo *et al.* (2013) turned their attention to South Korea from 1980 to 2009, utilizing panel data and OLS regression to highlight a mixed impact, predicting positive effects in the southern region and negative repercussions in the northern part. Shifting focus to the United States, Lobell *et al.* (2014) used panel data and OLS regression from 1980 to 2010, forecasting a decline in agricultural employment, predominantly impacting the southern and western regions. In the broader context of Africa, Mendelsohn *et al.* (2015) conducted a panel data analysis spanning 1980–2010, suggesting reduced agricultural employment, particularly in the western and southern regions.

A notable gap in the reviewed literature is the lack of comprehensive studies examining the holistic impact of climate change on agricultural sector employment in Nigeria. While various research has explored the link between climate change and agricultural productivity, very few studies have specifically addressed the implications for employment within this sector. This gap is significant because understanding how climate change affects agricultural employment is crucial for policymakers and stakeholders in Nigeria. Addressing this research gap is essential due to the significance of agriculture in the Nigerian economy and the vulnerability of the agricultural workforce to climate change. As climate change continues to affect weather patterns, crop yields, and farming practices, understanding its ramifications for employment is crucial for developing effective policies and interventions to support those dependent on the agricultural sector for their livelihoods.

Also, the empirical literature on climate change and its impact on agricultural sector variables in Nigeria employ various econometric techniques such as vector error correction models, auto-regressive distributed lag models, multinomial logit models, OLSs estimation, cointegration models, completely modified OLSs cointegration technique, multiple regression analysis, Computable General Equilibrium models, panel regression models, and Johansen cointegration tests. In contrast, this study introduces a significant improvement in estimation by employing the nonlinear autoregressive distributed lag (NARDL) model. This choice stands out due to its ability to capture both long-term and short-term dynamics in climate change relationships, incorporating asymmetries that may not be adequately addressed by traditional linear models. The NARDL model's unique feature lies in its capacity to address the nonlinear nature of climate change's influence on agricultural sector employment, providing a more nuanced understanding of the relationship. This approach presents a significant advancement over previous methods, offering a more comprehensive analysis of how climate change impacts employment within the Nigerian agricultural sector.

### 3. Methodology

In this section, the research methodology is introduced, encompassing the theoretical framework and model specification employed to assess the impact of climate change on agricultural sector employment in Nigeria.

#### 3.1. Theoretical framework

The theoretical framework adapted by this study is the sustainable livelihoods framework (SLF). It offers a comprehensive perspective on the intricate interplay between climate change, agricultural sector employment, and sustainable livelihoods in Nigeria. It takes into account five key types of assets crucial for livelihoods, including human, social, natural, physical, and financial capital. In the context of agriculture, these assets are essential for adaptation to climate change and the sustainability of employment in the sector. Human capital involves the knowledge and skills needed for climate-resilient farming practices, while social capital supports knowledge-sharing and community support. Natural capital encompasses land and water resources that can be affected by climate change, and physical capital includes critical infrastructure for agricultural activities. Financial capital, related to income and access to credit, is vital for investments in climate-resilient agriculture. Livelihood strategies, vulnerability context, and transforming structures and processes are examined within the framework, emphasizing the importance of adapting livelihood strategies in response to climate change, recognizing external influences, and considering institutional support for sustainable agriculture and employment.

The framework's relevance in the context of Nigeria is evident as climate change poses challenges to the agricultural sector. Shifts in rainfall patterns, temperature, and extreme weather events can impact crop yields and water resources, leading to vulnerability among smallholder farmers and disruptions in employment. Government policies and support structures play a significant role in enabling adaptation to climate change and sustaining employment in the agricultural sector. Effective policies that promote climate-smart agriculture, enhance access to credit, and improve market opportunities are critical for achieving sustainable livelihoods. Transforming the agricultural sector towards climate-resilient practices is essential for safeguarding employment opportunities and overall well-being amidst climate challenges.

In summary, the SLF provides a holistic approach to understanding how climate change affects agricultural sector employment and livelihoods in Nigeria. It emphasizes the importance of adaptive strategies, institutional support, and the management of various assets to enhance the resilience and sustainability of livelihoods in the face of climate change impacts in the agricultural sector. The SLF can be presented in a simplified algebraic representation to conceptualize the core elements as follows:

$$L = f(\text{HC}, \text{SC}, \text{NC}, \text{PC}, \text{FC}, \text{LS}, \text{VC}, \text{TS}, \text{O}), \quad (3.1)$$

where

- **L** represents Livelihoods.
- **HC** represents Human Capital, including knowledge, skills, and health.

- **SC** represents Social Capital, comprising relationships and networks.
- **NC** represents Natural Capital, encompassing land, water, and resources.
- **PC** represents Physical Capital, including infrastructure and tools.
- **FC** represents Financial Capital, involving income, savings, and access to credit.
- **LS** represents Livelihood Strategies.
- **VC** represents Vulnerability Context.
- **TS** represents Transforming Structures and Processes.
- **O** represents Outcomes, including income, food security, access to education and healthcare, and overall well-being.

This simplified algebraic representation is a conceptual model to illustrate that livelihoods are a function of various assets, strategies, external influences, and outcomes.

### 3.2. Data

This study used annual time series data covering the time frame of 1990–2019. The data for this study will be sourced from the Central Bank of Nigeria (CBN) Statistical bulletin, 2020 edition, World Bank Climate Change Portal and World Development Indicator (WDI) database of the United Nation Development Programme (UNDP).

### 3.3. Model specification

In order to assess the impact of climate change on agricultural sector employment, this study adapted the study of Oduyoye-Ejumedina and Ejumedina (2019) for the specification of the model employed for this objective.

The functional relationship of the model is specified as follows:

$$\text{Agemploy}_t = f(\text{AGDP}_t, \text{Openness}_t, \text{GFCF}_t, \text{Rain}_t, \text{Temp}_t), \quad (3.2)$$

where  $\text{Agemploy}_t$  is the percentage of agricultural sector employment as percentage of total employment in the country,  $\text{AGDP}$  is agricultural GDP as percentage of total GDP,  $\text{GFCF}$  is the gross fixed capital formation which is a proxy for investment.  $\text{Openness}$  measures the openness of the economy to international trade.  $\text{Rain}_t$  is the rainfall index (measured in Millimeters),  $\text{Temp}_t$  is the temperature index (measured in degree centigrade) and  $\alpha_0$ – $\alpha_4$  are the parameters to be estimated.

Given that Eq. (3.2) will be estimated using nonlinear asymmetric autoregressive distributed lag (NARDL), the long run asymmetric long-run equation specification is presented as follows:

$$\begin{aligned} \text{Agemploy}_t = & \alpha_0 + \alpha_1 \text{AGDPG}_t + \alpha_2 \text{Openness}_t + \alpha_3 \text{GFCF}_t + \alpha_4 \text{Rain}_t^+ + \alpha_5 \text{Rain}_t^- \\ & + \alpha_6 \text{Temp}_t^+ + \alpha_7 \text{Temp}_t^- + \mu_t. \end{aligned} \quad (3.3)$$

Following Shin *et al.* (2014), Eq. (3.3) can be presented in an ARDL framework as follows:

$$\begin{aligned} \text{Agemploy}_t = & \alpha_0 + \alpha_1 \text{Agemploy}_{t-1} + \alpha_2 \text{Openness}_t + \alpha_3 \text{GFCF}_t + \alpha_4 \text{Rain}_t^+ + \alpha_5 \text{Rain}_t^- \\ & + \alpha_6 \text{Temp}_t^+ + \alpha_7 \text{Temp}_t^- + \sum_{i=1}^l \rho_{1i} \Delta \text{Agemploy}_{t-1} + \sum_{i=0}^m \rho_{2i} \Delta \text{Openness}_{t-1} \end{aligned}$$

$$\begin{aligned}
 & + \sum_{i=0}^n \rho_{3i} \Delta \text{GFCF}_t + \sum_{i=0}^o \rho_{4i} \Delta \text{Rain}_{t-1}^+ + \sum_{i=0}^p \rho_{5i} \Delta \text{Rain}_{t-1}^- \\
 & + \sum_{i=0}^q \rho_{6i} \Delta \text{Temp}_{t-1}^+ + \sum_{i=0}^r \rho_{7i} \Delta \text{Temp}_{t-1}^- + \mu_t.
 \end{aligned} \tag{3.4}$$

All variables are explained above as  $l, m, n, o, p, q,$  and  $r$  denote the respective lag order.

Here  $\text{Rain}_t^+$  and  $\text{Rain}_t^-$  are the partial sum of positive and negative changes in mean of annual rainfall which is expressed as follows:

$$\text{Rain}_t^+ = \sum_{t=1}^t \Delta \text{Rain}_t^+ = \sum_{t=1}^t \max(\Delta \text{Rain}_t, 0), \tag{3.5}$$

$$\text{Rain}_t^- = \sum_{t=1}^t \Delta \text{Rain}_t^- = \sum_{t=1}^t \max(\Delta \text{Rain}_t, 0). \tag{3.6}$$

While  $\text{Temp}_t^+$  and  $\text{Temp}_t^-$  are the partial sum of positive and negative changes in mean of annual temperature which can also be expressed as follows:

$$\text{Temp}_t^+ = \sum_{t=1}^t \Delta \text{Temp}_t^+ = \sum_{t=1}^t \max(\Delta \text{Temp}_t, 0), \tag{3.7}$$

$$\text{Temp}_t^- = \sum_{t=1}^t \Delta \text{Temp}_t^- = \sum_{t=1}^t \max(\Delta \text{Temp}_t, 0). \tag{3.8}$$

### 3.4. Estimation procedure

The NARDL model, also known as asymmetric autoregressive distributed lag (ARDL), was used in this study. The ARDL technique is chosen because it may be used effectively regardless of whether the data are stationary at level, at first difference, or mixed. Based on the claim made by Mendelsohn *et al.* (1994) that the link between climate change and the agricultural sector is nonlinear, NARDL is also relevant.

The NARDL technique provides a robust dynamic parameter framework capable of capturing both long-term and short-term asymmetries in relationships (Pesaran *et al.*, 2001). Its unique strength lies in integrating nonlinearity into the conventional ARDL methodology by simultaneously incorporating partial sum dynamic adjustments (Shin *et al.*, 2014). This distinctive feature enables NARDL to effectively capture both the escalation and decline of climate change, setting it apart from other estimation methods commonly employed in climate change studies.

Like its linear version, the asymmetric ARDL modeling approach used in this study has various benefits, one of which is that it can be used regardless of whether the model's variables are stable at level or at first difference. Additionally, this approach accounts for serial correlation and endogeneity while also allowing for potential asymmetric adjustments to the movement of the variables. Asymmetric ARDL was used as a modeling tool for this study in part in order to benefit from the nonlinear modeling methods. For instance,

linear models contain symmetry qualities that imply shocks experienced during a recession are just as durable as those experienced during an expansion of the business cycle. A nonlinear relationship between climate change and the agricultural sector has been established in the literature, and it is preferable to treat climate change's impact as nonlinear because it can result in either an increase or decrease in climatic variables like rainfall and temperature. As a result, linear models may be too limited in this situation.

The first step in the asymmetric co-integrating relationship under the NARDL is to decompose the exogenous variable into partial sum processes as follows:

$$Y_t = \beta^+ X_t^+ + \beta^- X_t^- + \mu_t \quad \Delta E_t = V_t, \tag{3.9}$$

where  $Y_t$  is a  $k$  by 1 vector of agricultural output at time  $t$ ;  $X_t$  is  $k$  by 1 vector of multiple regressors defined such that  $X_t = X_0 + X_t^+ + X_t^-$ , representing variables of climate change;  $\mu_t$  is the error term;  $\beta^+$  and  $\beta^-$  are the associated asymmetric long-run parameters, indicating that agricultural sector responds asymmetrically during up and down periods of climate change.  $X_t^+$  and  $X_t^-$  are partial sum processes of the positive (+) and negative (-) changes in  $X_t$  defined as follows:

$$E_t^+ = \sum_{j=1}^t \Delta E_{j=1}^+ = \sum_{j=1}^t \max(\Delta E_j, 0), \quad E_t^- = \sum_{j=1}^t \Delta E_{j=1}^- = \sum_{j=1}^t \min(\Delta E_j, 0). \tag{3.10}$$

If Eq. (3.9) is estimated with OLS estimator to calculate the cointegration parameter, some problems such as endogeneity and serial correlated error can come up. Therefore, estimating the cointegration parameter would be poorly determined in an infinite sample. The solution to these problems is to employ the ARDL approach advanced by Pesaran *et al.* (2001). The ARDL approach is a flexible, dynamic parametric framework appropriate for the modeling of long-run and short-run asymmetries.

### 3.5. Econometric tests

In order to determine the reliability or otherwise of the estimation techniques adopted for this study, some econometric tests such as unit root test and Wald test were carried out.

#### 3.5.1. Unit root test

Unit root test is employed to determine the order of integration of the variables. Although NARDL model is appropriate for variables that have order of integration at level ( $I(0)$ ) and at first difference ( $I(1)$ ) but not appropriate for variables that are stationary at second difference ( $I(2)$ ). Therefore, testing for unit root is important to avoid variables that at  $I(2)$ . To achieve this, this study will use Augmented Dickey Fuller (ADF) test.

#### 3.5.2. Wald test

The Wald test is a test statistic based on the unrestricted regression. It assesses constraints on statistical parameters on the weighted distance between the unrestricted estimate and it hypothesized value. It shows how close the unrestricted estimates come to satisfying the

restricted hypothesis. In the case of this study, this test procedure will be used to test for the existence of asymmetry in the nonlinear ARDL model.

#### 4. Empirical Results and Discussion

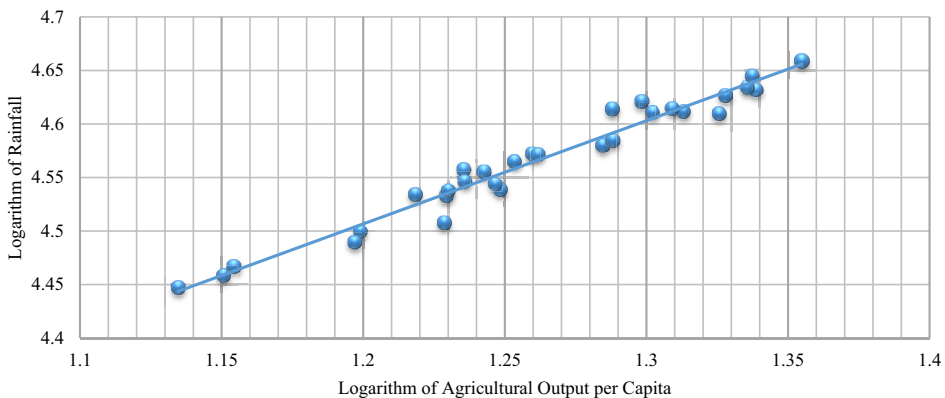
In order to determine the impact of climate change on agricultural sector employment in Nigeria during the period under study, the study carried out various tests as well as the estimation of both the short-run and long-run model of the relationship between climate change and agricultural sector employment in Nigeria.

##### 4.1. Trends of climatic indices and agricultural output

The data presented in Figs. 1 and 2 offer critical insights into the relationship between climate variables, specifically mean annual rainfall and mean annual temperature, and their impact on agricultural output per capita in Nigeria. These findings are of utmost importance in understanding the vulnerability of the agricultural sector to climate change and its implications for food security and livelihoods. Let us delve deeper into the implications of these relationships:

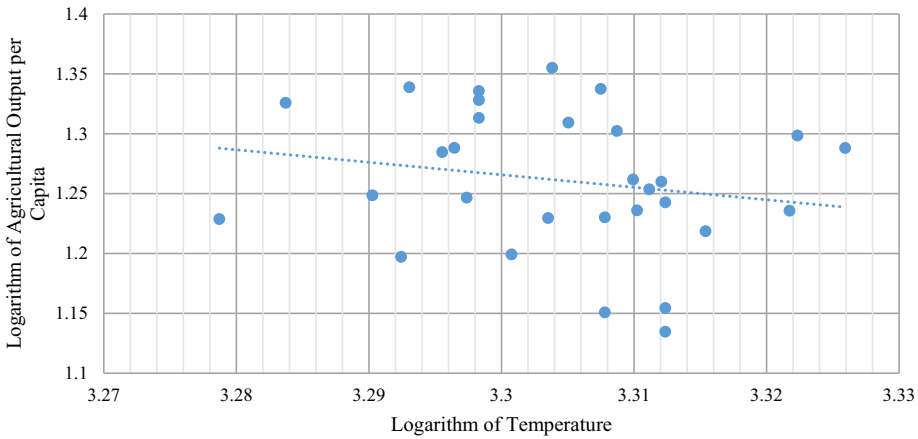
Figure 1 provides a clear illustration of a positive correlation between mean annual rainfall and agricultural output per capita in Nigeria. As mean annual rainfall increases, there is a corresponding increase in the output of the agricultural sector. This finding underscores the fundamental role of adequate rainfall in promoting agricultural productivity and output.

The positive relationship between rainfall and agricultural output holds significant implications for Nigeria's food security and economic growth. Adequate rainfall is essential for crop growth, as it provides the necessary moisture for plants. This relationship suggests that regions with higher and more consistent rainfall levels are better equipped to support



Source: Made by the author.

Fig. 1. A scatter plot of the trend of rainfall and agricultural output per capita (1990–2020).



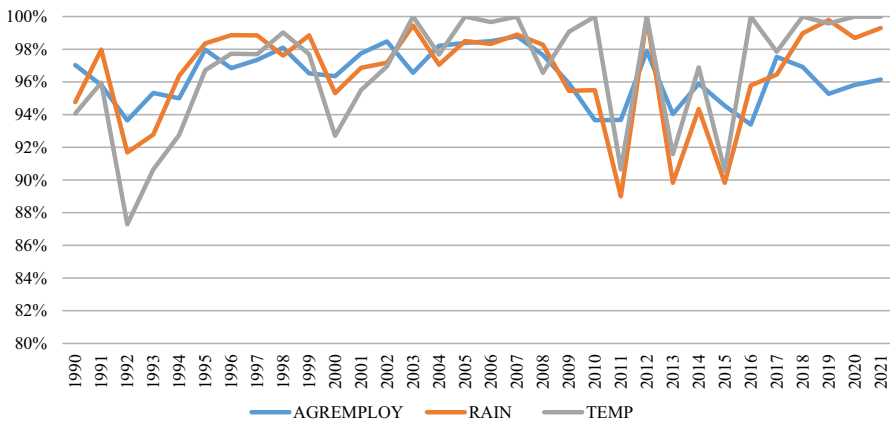
Source: Made by the author.

Fig. 2. A scatter plot of the trend of temperature and agricultural output per capita (1990–2020).

robust agricultural activities and higher crop yields. Therefore, it emphasizes the importance of climate-resilient agricultural strategies and water management practices to harness the benefits of increased rainfall.

Figure 2 reveals an equally significant trend, albeit in the opposite direction. The scatter plot depicts a negative relationship between mean annual temperature and agricultural sector output per capita in Nigeria. As mean annual temperature increases, there is a decrease in the output of the agricultural sector. This negative relationship between temperature and agricultural output raises critical concerns about the impact of climate change on agricultural productivity. Rising temperatures can have adverse effects on crop growth and livestock health. Higher temperatures can lead to reduced crop yields, increased stress on livestock, and challenges related to water availability. These factors collectively result in decreased agricultural output and lower food production, posing a substantial threat to food security and livelihoods.

The negative relationship between temperature and agricultural output reinforces the urgency of climate change mitigation and adaptation efforts in the agricultural sector. Strategies such as the adoption of heat-tolerant crop varieties, improved irrigation methods, and the implementation of climate-smart agricultural practices become imperative in the face of increasing temperatures. In conclusion, the data analysis presented in Figs. 1 and 2 highlights the critical and opposing relationships between climate variables and agricultural sector output in Nigeria. While increased rainfall positively contributes to agricultural productivity, rising temperatures have a detrimental impact. These findings underscore the need for proactive climate-resilient agricultural policies and practices that can help mitigate the adverse effects of climate change and ensure food security and sustainable livelihoods for Nigeria’s population. Policymakers, researchers, and stakeholders should prioritize these considerations in efforts to build a more resilient and productive agricultural sector in the face of a changing climate.



Source: Made by the author.

Fig. 3. Trends of climate change and agricultural sector employment.

Figure 3 presented a graph showing agricultural employment, rainfall and temperature trends in Nigeria from 1990 to 2021. The figure indicated that agricultural employment has declined steadily over the period, from around 50% in 1990 to 34% in 2021. Rainfall patterns show high year-to-year variability, with both positive and negative anomalies observed. No clear long-term trend is discernible, though severe droughts (negative rainfall anomalies) occurred in 1993, 2011, and 2013. Temperature also exhibits fluctuations but shows an overall gradual increasing trend since the 1990s. Rising temperatures could be playing a role in making agriculture less viable and attractive over time.

Some periods with declines in agricultural employment align with negative rainfall anomalies, such as in the early 1990s, early 2000s and around 2011–2013, indicating potential impacts of drought on agricultural livelihoods. However, agricultural employment continues to decline even in years with positive rainfall anomalies, suggesting other structural factors are also at play beyond just climate variations. In summary, the data indicate variable rainfall and rising temperatures in Nigeria over the past three decades. Agricultural employment has steadily declined during this period, which can be partially attributed to climate factors.

#### 4.2. Unit root test results

The standard ADF unit root test is presented in Table 1. It revealed that AGDP, GFCF, and RAIN were stationary at level while AGREMPLOY, OPENNESS and TEMP are stationary at first difference. Hence, the time series data employed in this study were stationary either  $I(0)$  or  $I(1)$ .

#### 4.3. Bound cointegration test results

The results of the bound test for existence of long-run relationship are presented in Table 2. The bound test results indicated that  $F$ -statistics value of 4.65 is greater than upper and lower critical values. Therefore, these results confirmed the existence of long-run relationship



Table 1. ADF unit root test.

Variables	ADF statistics at level		ADF statistics at first difference		Order of integration
	ADF Statistics	Prob.	ADF Statistics	Prob.	
AGREMPLOY	-0.0048	0.9459	-3.59475	0.0259	I(1)
AGDP	-3.2234	0.0291	-4.9582	0.0005	I(0)
GFCF	-4.7554	0.0037	-8.9785	0.0000	I(0)
OPENNESS	0.1368	0.9632	-3.8806	0.0063	I(1)
RAIN	-6.6550	0.0000	-12.8706	0.0000	I(0)
TEMP	-2.6442	0.0960	-4.2924	0.0025	I(1)

Source: Made by the author.

Table 2. Bound test.

Test statistic	Value	Signif.	I(0)	I(1)
<i>F</i> -statistic	4.658838	10%	2.12	3.23
<i>K</i>	6	5%	2.45	3.61
		2.5%	2.75	3.99
		1%	3.15	4.43

Source: Made by the author.

in the model and as such both the short-run and long-run models can be estimated using the nonlinear ARDL estimation technique.

**4.4. Short-run model of climate change and agricultural sector employment**

The short-run model that examined the impact of climate change on employment in the agricultural sector is presented in Table 3. The results revealed that negative index of rainfall has a positive impact on employment in agricultural employment which is statistically significant at 5% level. A unit reduction in rainfall index resulted in 0.083 increase in agricultural sector employment. This can be attributed to the fact that less rainfall means more working hours for humans as working while it is raining may be unbearable. The lagged (past) value of reduction in rainfall index has a negative impact on employment in the agricultural sector that is statistically significant at 5% level. A unit increase in lagged value of negative index of rainfall resulted in 0.0919 reduction in agricultural sector employment. This reduction in agricultural sector’s employment may not be unconnected with the destruction that drought and shortages of water can cause by reduction in rainfall.

Increase in temperature index has a negative impact on employment in the agricultural sector which is not statistically significant at 5% level. A unit increase in the positive index of temperature resulted in ₦0.047 billion decrease in agricultural sector employment. The lagged (past) value of positive index of temperature led to a reduction in agricultural sector employment that is statistically significant at 5% level. A unit increase in the positive index of temperature is accompanied by ₦0.1808 billion reduction in agricultural sector employment. This results revealed that rising temperature is detrimental to agricultural sector’s employment.

The negative index for temperature has a positive impact on employment in the agricultural sector which is also statistically significant at 5% level. A unit increase in the negative index of temperature results in ₦0.094 billion increase in agricultural sector employment. The lagged (past) value of negative index of temperature has a positive impact on agricultural sector employment. A unit increase in the lagged value of negative index of temperature results in ₦0.094 billion increase in agricultural sector employment.

Agricultural sector contribution to gross domestic product (AGDP) has negative impact on agricultural sector employment both as current and lag, while openness of the economy to international trade has positive impact on agricultural sector employment though not statistically significant at 5% level. Also, GFCF has positive impact on agricultural sector employment that is not statistically significant at 5% level. The lagged value of GFCF has a positive impact on agricultural sector employment statistically significant at 5% level.

The speed of adjustment is rightly signed and statistically significant at 5% level and indicated that 14% of variation caused by shocks from the long-run is corrected annually. This means that within a period of eight years, deviation from long-run equilibrium position will be fully corrected. The adjusted coefficient of determination indicated that the model explained 96% of the total variation in agricultural sector employment. Also, the Durbin-Watson statistics of 2.38 which can be approximated to 2 indicated the absence of autocorrelation.

#### 4.5. Long-run model of climate change and agricultural sector employment

Table 4 revealed the long-run impact of climate change on agricultural sector employment. It indicated that both positive and negative indices of rainfall have negative impact on agricultural sector employment in the long-run though the impact of the positive index of rainfall is statistically significant at 5% level while that of negative index of rainfall is statistically insignificant at 5% level. A unit change in the positive and negative indices of rainfall leads to 1.066 and 1.82 unit reduction in agricultural sector employment, respectively. Also, the negative and positive indices of temperature have a negative impact on

Table 3. Short-run model of climate change and agricultural sector employment.

Variable	Coefficient	Std. error	t-statistic	Prob.
D(AGREMPLOY(-1))	0.726107	0.052291	13.88594	0.0000
D(AGDP)	-0.007241	0.010731	-0.674784	0.5249
D(AGDP(-1))	-0.060735	0.011185	-5.430237	0.0016
D(OPENNESS)	0.466994	0.272880	1.711350	0.1379
D(GFCF)	4.66E-12	1.95E-12	2.382549	0.0546
D(GFCF(-1))	1.10E-11	2.05E-12	5.364314	0.0017
D(RAIN_NEG)	0.083833	0.020402	4.109025	0.0063
D(RAIN_NEG(-1))	-0.091976	0.018848	-4.879901	0.0028
D(TEMP_POS)	-0.047047	0.029648	1.586832	0.1636
D(TEMP_POS(-1))	-0.180805	0.024821	-7.284259	0.0003
D(TEMP_NEG)	0.094391	0.033561	2.812531	0.0307
D(TEMP_NEG(-1))	0.093693	0.042911	2.183415	0.0717
CointEq(-1)*	-0.142238	0.017050	-8.342272	0.0002

Table 3. (Continued)

Variable	Coefficient	Std. error	t-statistic	Prob.
R-squared	0.978845	Mean dependent var		-0.571852
Adjusted R-squared	0.960712	S.D. dependent var		0.304834
S.E. of regression	0.060421	Akaike info criterion		-2.468763
Sum squared resid	0.051110	Schwarz criterion		-1.844842
Log likelihood	46.32830	Hannan–Quinn criterion		-2.283239
Durbin–Watson stat	2.387230			

Source: Made by the author.

Table 4. Long-run model of climate change and agricultural sector employment.

Variable	Coefficient	Std. Error	t-statistic	Prob.
AGDP	0.001238	0.005979	0.207003	0.8383
OPENNESS	-0.297110	0.088419	-3.360250	0.0007
GFCF	1.288838	3.498106	0.368439	0.7168
RAIN_POS	-1.066309	0.381160	-2.797536	0.0029
RAIN_NEG	-1.821267	6.284576	-0.289799	0.7753
TEMP_POS	-3.322369	8.535791	-0.389228	0.7017
TEMP_NEG	-2.347533	5.690319	-0.412549	0.6848

Source: Made by the author.

agricultural sector employment. A unit increase in the positive and negative indices of temperature leads to 1.8212 and 3.3223 unit reduction in agricultural sector employment in Nigeria. Though the impacts are not statistically significant at the 5% level of significance. These results revealed a negative relationship between climate change and agricultural sector employment in Nigeria in the long-run.

AGDP has a positive impact on agricultural sector employment though the impact is also not statistically significant in the long run. Openness of economy to international trade has a negative impact on agricultural employment that is statistically significant at 5% level. GFCF also has a positive impact on agricultural sector employment though the impact is not statistically significant at 5% level.

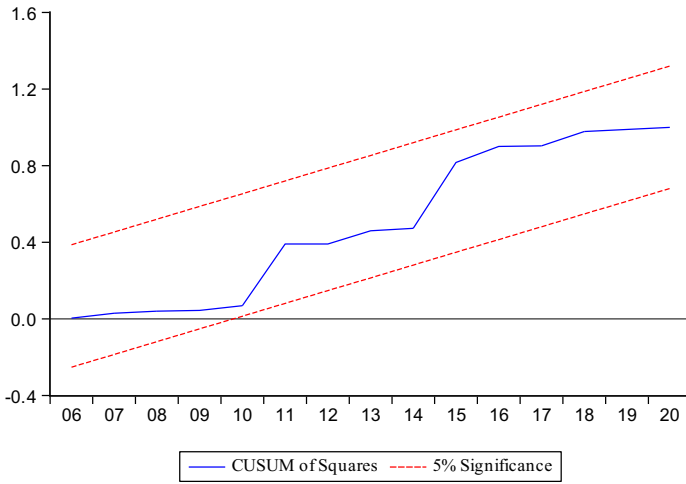
**4.6. Stability test results**

The results of the CUSUM of square test presented in Figs. 4 and 5 revealed that the plot of the CUSUMSQ falls within the two straight lines indicating that the model is stable.

**4.7. Wald test**

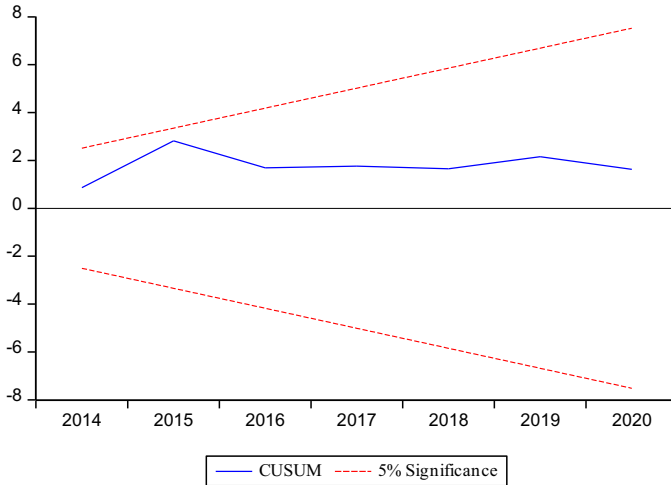
Wald test results reported in Table 5 revealed F-test and Chi-square critical values of 5.90 and 11.81 with probability values of 0.0164 and 0.0027, respectively. Therefore, based on these results, the null hypothesis of linearity is rejected and the existence of nonlinearity is confirmed.

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Source: Made by the author.

Fig. 4. NARDL CUSUM of square graph.



Source: Made by the author.

Fig. 5. NARDL CUSUM graph.

Table 5. Wald test for rainfall.

Test statistic	Value	Df	Probability
F-statistic	5.905581	(2, 12)	0.0164
Chi-square	11.81116	2	0.0027

Source: Made by the author.

## **5. Conclusion and Recommendations**

In conclusion, this study has provided valuable insights into the relationship between climate change and agricultural sector employment in Nigeria. The empirical findings revealed both short-term and long-term impacts of climate variables, particularly rainfall and temperature, on agricultural employment. From empirical analysis, this study found that climate change has significant implications for employment in the agricultural sector. Reduced rainfall can lead to increased employment due to the need for more working hours when it is not raining. However, the negative impact of drought and water shortages on employment is also observed. Rising temperatures are detrimental to agricultural employment, leading to reduced output and potential challenges for the sector.

This study's findings must be viewed within the constraints of the data's temporal and spatial scope. Utilizing annual time series data from 1990 to 2019 presents limitations, as a longer time series with higher frequency data, such as monthly or quarterly, could offer a more detailed understanding of the intricate dynamics between climate change and employment in agriculture. Moreover, the analysis focusing on aggregate national trends overlooks potential variations obscured by regional, state-level, or farm-specific dynamics. Additionally, the study lacks the ability to disentangle the influence of various other factors such as technological advancements, educational enhancements, and population growth on agricultural sector employment, thereby limiting a comprehensive understanding of the exclusive impact of climate change on employment in the agricultural sector.

Based on the findings of this study, several recommendations can be made to address the challenges posed by climate change on agricultural sector employment in Nigeria:

- (1) Given the significant impact of rainfall on agricultural sector employment, it is essential to implement strategies for managing and optimizing rainfall. This includes investments in water harvesting and storage systems to mitigate the negative effects of reduced rainfall. Also, promotion of affordable irrigation techniques like small-scale drip and sprinkler systems to help smallholder farmers withstand dry spells should be encouraged.
- (2) Addressing the negative impact of rising temperatures on agricultural employment is crucial. This can be achieved by promoting the adoption of heat-tolerant crop varieties and implementing cooling technologies to protect livestock. In addition, setting up community seed banks to improve access to drought-tolerant and early maturing crop varieties can also help reduce the negative impact of climate change on agricultural sector employment.
- (3) Expansion of agricultural extension services and farmer field schools to rural areas and small holder farmers focused on climate-smart agriculture.
- (4) Provision of smallholder farmers' better access to climate information services and weather index-based insurance.
- (5) Development and promotion of drought-resilient agricultural practices, such as efficient irrigation techniques and the cultivation of drought-resistant crops, to mitigate the adverse effects of reduced rainfall.

## ORCID

Kehinde Samuel ALEHILE  <https://orcid.org/0000-0002-5519-5015>

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