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Climate Change and Agricultural Production Trends in Nigeria

BACHELOR'S THESIS

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Declaration

I hereby declare that I have done this thesis entitled "Climate change and agricultural production trends in Nigeria" independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references.

In Prague, April 2022

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Abiodun Segun Ogundele

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Abstract

This study was conducted to investigate the effect of climatic variability on agricultural production in Nigeria over a period of two decades (1999 – 2018) using secondary data obtained from Food and Agriculture Organisation, World Bank and Central Bank of Nigeria. Climate data used include rainfall, average temperature, minimum temperature, and maximum temperature. Agricultural production data used include cassava yield, maize yield, chicken production and goats' production in Nigeria. Descriptive statistics, Mann-Kendall's trend test, and Pearson correlation were used to analyse the data using Microsoft Excel and Statistical Package for Social Sciences (SPSS) version 26. The result revealed an insignificant decrease ($R^2 < 0.028$, p=0.92) in annual rainfall. The result also revealed an increasing average temperature trend with Kendall's tau value of 0.39. The minimum temperature also increased linearly with time. It varied from 20.71^0C to 21.71^0C averaging to 21.41^0C and statistical analysis reveals that the increase was statistically strong ($R^2>0.5$) and significant ($p<0.05$) with Kendall's tau value of 0.59. Significant positive association was recorded among average temperature and maize yield (0.474, $p<0.05$), goats' production (0.477, $p<0.05$), and chickens' production (0.613, $p<0.01$). This study concludes that increased temperature and decreased precipitation over time in Nigeria have significant effect on crop yields and livestock production. which are projected to increase under climate change and could directly threaten crop yields and livestock production. Hence, it is recommended that diversified coping and adaptation mechanisms should be undertaken and improved crop varieties and livestock breeds that can survive under changed climate conditions should be introduced to farmers.

Keywords: climate, rainfall, temperature, agriculture, yield, livestock

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1. Introduction

Climate change is one of the environmental life-threatening to the economic development and sustainability of humanity worldwide (Bello et al., 2012). Natural climate cycle and human activities have contributed to an increase in the accumulation of heat-trapping “greenhouse” gases in the atmosphere, thereby contributing to an increase in temperature in the global climate (global warming) (Cheng et al., 2021). Global warming causes unpredictable and extreme weather events impact and increasingly affect crop growth, availability of soil water, forest fires, soil erosion, droughts, floods, sea level rises with prevalent infection of diseases and pest infestations (Abubakar et al., 2021). These environmental problems result in low and unpredictable crop yields, making farmers more vulnerable, especially in Africa (Salahuddin et al., 2020).

Climate change and agriculture are interrelated processes, both of which take place on global scale. Global warming is projected to have a significant impact on conditions affecting agriculture, including temperature, carbon dioxide, glacial run-off, precipitation, and the interactions of these elements (Azare et al., 2020). The overall effect of climate change on agriculture depends on the balance of these effects. Assessment of the effects of global climate changes on agriculture might help to properly anticipate and adapt farming to maximize agricultural production (Azare et al., 2020). What has changed in the last few hundred years is the additional release of carbon dioxide by human activities, fossils and fuels burned to run cars and trucks, heat homes, businesses and power factories are responsible for about 98% of the U.S emission of carbon dioxide, 24% of methane and 18% of nitrous oxide (Azare, 2014).

There is growing evidence that climate change, specifically higher temperatures, altered patterns of precipitation and increased frequency of extreme events such as drought and floods, is likely to depress crop yields and increase production risks in many world regions (Bagamba et al., 2012). There are many factors influencing crop production, and these include soil, relief, climate, pests, and diseases, among others. In relation to climate, rainfall is the dominant controlling variable in tropical agriculture since it supplies soil moisture for crops and grasses as fodder (Azare et al., 2020). Agriculture depends on climate to function. Hence, precipitation, solar radiation, wind, temperature, relative humidity, and other climatic parameters affect and solely determine the global distribution of crops and livestock and their proclivity to higher yields or outputs (Azare, 2014).

The growing problem of climatic change impacts is global and the developing countries, especially Africa will be mostly affected. This is because the African economy is agrarian rain-fed, fundamentally dependent on the vagaries of weather, due to inability to cope due to poverty and low technological development, hence the farmers' low level of cropping capabilities by the farmers (Olajumoke et al., 2020). It is projected that crop yield in Africa may fall by 10-20% by, 2050 or even up to 50% due to climate change (Alemu and Mengistu, 2019).

Available evidence showed that Nigeria is already being plagued with diverse ecological problems linked to the on-going climate change (Okorie et al., 2020). The southern ecological zone of Nigeria known for high rainfall is currently confronted by irregularity in the rainfall pattern, while the Guinea savannah experiencing gradually increasing temperature.

The Northern zone faces the threat of desert encroachment at a fast rate per year occasioned by fast reduction in the amount of surface water, flora, and fauna resources on land (Akinbami and Akinbami, 2017).

Due to these environmental threats resulting to declining in crop yields, some farmers in Nigeria are abandoning farming for non-farming activities (Nwalem et al., 2019). Hence, concerted efforts toward tackling these menaces are necessary. The study of the effect of climate change on agricultural productivity is therefore critical, given its impact in changing livelihood patterns in the country. However, for a reasonable conclusion to be drawn on weather data, at least a century of evaluation of climate trend with clear and permanent impacts on the ecosystem is very imperative (Petersen, 2019). Therefore, on this premise, there is the need to examine the concept of climate change using temperature and rainfall data and its impact on agricultural productivity in Nigeria.

2. Aims of the Thesis

2.1 Overall Objective

The main objective of this study is to assess the effect of climatic variability on agricultural production in Nigeria.

2.1.1 Specific Objectives

The specific objectives of this study are to:

1. Explore the trend in climate variation in Nigeria over a period of two decades.
2. Assess the trend in agricultural production in Nigeria over a period of two decades.
3. Identify the relationship between climate variability and agricultural production in Nigeria over a period of two decades.

3 Literature Review

3.1 Concept of Climate Change

Climate is the weather condition of an area over a few years (Zhang et al., 2016). It is the regular pattern of weather conditions of a particular place. The Intergovernmental Panel on Climate Change (IPCC, 2014) glossary definition shows that:

> *"Climate is the average weather within a given duration. It is the statistical description in terms of the mean and variability of relevant quantities over a period ranging from months to thousands or millions of years. The classical period is usually 30 years, and the quantities are most often surface variables such as temperature, precipitation, and wind."*

Climate is the typical weather conditions experienced at any location or area over series of years. Weather conditions such as rainfall, sun intensity, surface temperature and other meteorological elements recorded on interval for years and the average taken at the end of the targeted period is referred to as the climate of the location where such data were collected. Over the historical period, there have been a few constant variables that determine climate, including latitude, altitude, the proportion of land to water, and proximity to oceans and mountains (IPCC, 2014). Many global issues are related to climate, such as the supply of basic needs such as food, water, health, and shelter. Unfavourable climate variations may threaten basic needs with increased temperatures, sea level rise, changes in precipitation, and more frequent or intense extreme events (Cramer et al., 2018). It is predicted that food security, water and other key natural resources may be threatened by climate change.

Climate change is the significant and lasting variation in the average weather system's statistical properties when considered over an extended period, regardless of cause (IPCC, 2014). Climate change can be referred to as the variation in average weather attributed directly or indirectly to human activities and natural events that alter the composition of the atmosphere over comparable period. The term is sometimes used to refer specifically to climate variation caused by human activities instead of earth's natural processes (Nwankwoala, 2015). Climate change is a long-term shift in the weather condition of a specific location, region, or planet. The shift is measured by changes in features associated with average weather, such as temperature, wind patterns and precipitation (Swain et al., 2016). It could be a shift in average weather conditions or the distribution of weather around the average conditions (IPCC, 2014). In the context of environmental policy, the term climate change has become synonymous with anthropogenic global warming, which is the rise in average surface temperature (IPCC, 2014).

Global warming is the heating of the earth’s surface which results when the atmosphere traps heat radiating towards space (Herndon, 2018). Global warming summarizes the term referring to the increase in the surface temperature of the earth. Climate change includes global warming and everything else affected by increasing greenhouse gases (GHG) level (IPCC, 2014). When the average weather of a specific region is altered between two different time periods, then climate change is said to have occurred (Ray et al., 2019).

Climate change usually occurs when there is an alteration in the total amount of the sun's energy absorbed by the earth's atmosphere and surface. It also happens when there is a change in the amount of heat energy from the earth's surface and atmosphere that escapes to space (the area beyond earth's atmosphere) over an extended period (Adedeji, 2014). The average weather system generates an area's climate, which has five components: atmosphere, hydrosphere, cryosphere, land surface, and biosphere (IPCC, 2011). Scientists actively work to understand past and future climate by using observations and theoretical models. Borehole temperature profiles, ice cores, floral and faunal records, glacial and periglacial processes, stable isotope, sea level records and other sediment analyses provide a climate record that spans the geological past (Mesarović, 2019).

Physically based general circulation models are often used in theoretical approaches to match past climate data, link causes and effects and make future projections. In other words, what is observed now is compared with what was known, to determine and understand the changing trend of climate. Recent data are provided by the instrumental records, which indicate the activities that lead to climate change. The activities that lead to climate change are broadly classified into anthropogenic causes (human-activity-related) and natural causes (earth's natural activities which are the non-human-activity-related) (Dunlap and McCright, 2015).

3.1.1 Anthropogenic Causes

Earth is heated up by the sun which serves as natural source of warmth thus generates the needed temperature for life forms and other activities on the planet. Most of the sun's energy (heat) passes through space to reach and warm the atmosphere, earth's surface, and oceans. The rate at which energy is received from the sun and the rate at which it is lost to space determine the equilibrium temperature and climate of the earth (IPCC, 2014). To keep the atmosphere's energy budget in balance, the warmed earth emits heat (energy) back to space as infrared radiation (Anderson et al., 2016). As the energy radiates upward, most is absorbed by existing clouds and molecules of greenhouse gases in the lower atmosphere. The emitted energy goes in all directions, some back towards the surface of the earth and some upwards, where other molecules higher up absorb the energy (Adedeji, 2014). This process of absorption and re-emission is repeated until finally, the energy escapes to the area beyond earth's atmosphere called space.

This natural process is known as the greenhouse effect which keeps earth's energy budget in balance. In the era leading to climate change, however, much of the energy is blocked and reflected downwards due to increased GHG, causing earth's surface temperatures to become much warmer than usual (Adedeji, 2014). Without the abundance of the GHG, earth's average temperature would be -19°C instead of +14°C (Farmer and Cook, 2013). Scientists agree that the main cause of the current global warming trend is human's increase of the GHG in the atmosphere, which blocks heat from escaping to the space (Idiata, 2016).

Over the past centuries, the amount of GHG (greenhouse gases) in the atmosphere has been stable until its concentrations began to increase, due to the rising demand for energy caused by industrialization, high population, changing land use, bush burning and human settlement patterns (IPCC, 2011), which have resulted to climate change. The earth's climate has changed throughout history, but the current warming trend is of particular significance because most of it is human-induced and occurring at an unmatched rate for the past centuries (Gabriele 1996). In its recently released of the Fourth Assessment Report, the Intergovernmental Panel on Climate Change, a group of 1,300 independent scientific experts from countries all over the world under the auspices of the United Nations, concluded that there is more than 90% probability that human activities over the past centuries have warmed planet earth (IPCC, 2014). The report also concluded that there is a greater than 90% probability that human produced GHG such as CO_2, methane (CH_4) and nitrous oxides (NOx) have caused much of the observed increase in earth's temperature in the last century.

Over the last century, the burning of fossil fuels like coal and oil, and the increased level of deforestation has raised the concentration of atmospheric gases such as CO2 (IPCC, 2014). Industrial and other steam engines are also known to release CO_2. The clearing of land for agriculture, industry, and other human activities have also contributed to the abundance of GHG in the atmosphere. Trees and other smaller plants replenish the atmosphere with Oxygen (O_2) while utilizing the available CO_2 during photosynthesis (Osinem, 2005). During respiration, the trees and grasses inhale CO_2 and exhales O_2. This process decreases the harmful level of CO_2 in the atmosphere and increases the supply of O_2.

The variation in the supply and utilization of CO_2 affects the percentage composition of gases in the GHG layer in the atmosphere. The GHG layer primarily contains water vapour and other gases such as CO_2, methane (CH_4), nitrous oxides (NOx) and chlorofluorocarbons (CFCs) (IPCC, 2014).

The GHG layer at normal and balanced composition of gases acts as a thermal blanket for the earth, absorbing heat and warming the surface to a life-supporting average of 59^{o}F (15°C), (Ussiri. and Lal, 2017). Excess or deficient supply of any of the GHGs (greenhouse gases) affects the balance of the GHG layer. The GHGs when in excess supply in the GHG layer block heat from escaping from the earth's atmosphere into space. The excess long-lived GHGs which remain semi-permanent in the atmosphere, and do not respond physically or chemically to changes in temperature, are described as "forcing" climate change whereas gases, such as water vapour, which respond physically or chemically to changes in temperature are known as "feedbacks" (Lockwood, 2012).

In summary, human activities which are regarded as the anthropogenic causes of climate change include, the release of CO_2 and other greenhouse gases through burning of fossil fuel, gas flaring, emissions from combustion engines and other numerous industrial activities. Others include, but not limited to, deforestation and clearing of land as well as urbanization.

3.1.2 Natural Causes

This refers to the non-anthropogenic (non-human-related) activities that are of natural processes. Natural causes of climate change include variations in ocean currents (which can alter the distribution of heat and precipitation), orbital variation (alteration of the earth's eccentric, angular and precession axis), solar output (variation in sun's intensity), plate tectonics (motion resulting from deformation of rocks) and large eruptions of volcanoes, which can sporadically increase the concentration of atmospheric particles, blocking out more sunlight (Cramer et al., 2018). Climate change can be attributed to variations in earth's orbiting which alters the amount of solar energy that the earth planet receives (Lockwood, 2012). The energy from the sun is distributed around the globe by wind, ocean currents, and other mechanisms to affect the climates of different regions (Anderson et al., 2016). Thus, a change in the direction and speed of global wind and ocean currents results in a variation in the distribution pattern of solar energy, which directly alters the distribution of solar energy distribution, which directly alters the average weather of earth, particularly in regions surrounded by water bodies.

These causative activities natural and man-induced have resulted to chemical and physical change of activities on earth, most of it is not favourable to the environment and occupants of earth; plants and animals, and their effects are visible on earth.

3.2 Perceptions of Climate Change

Critical research areas on themes relating to impacts and responses of climate variability and change and livelihoods have been identified in dryland ecosystems (Maestre et al., 2012). Considering different people experience climate change differently, the degree of household vulnerability varies even after exposure to the same climate signal.

For example, a pastoralist and agriculturalist will feel different impacts in terms of lowered crop yields versus walking further distance to water livestock (Quandt and Kimathi, 2017). It is clear in the literature that perceptions of climate change are necessary before adopting adaptive strategies (Uddin et al., 2014; Hügel and Davies, 2020). For example, to adapt to climate change, farmers or pastoralists must first notice that the climate has altered to be able to identify and implement potentially useful adaptations (Silvestri et al., 2012). Additionally, these perceptions may vary based upon roles within the household and community which mediate access to resources and shape an individuals' worldview (Quandt, 2018; Quandt, 2020).

3.3 Agriculture Sector in Nigeria

Agricultural sector is the most important sector of the Nigerian economy which holds a lot of potentials for the future economic development of the nation as it had done in the past.

The country has been relying on revenue generated from crude oil to sustain its economy after it shifted from agriculture in the 1960s which had been the main source of its revenue (Sertoglu, Ugural & Bekun 2017.) However, since 2nd quarter of 2014, global crude oil price declined and this, in turn, has reduced the revenue generated by the Nigerian government with the inability of the country to diversify its source of revenue and foreign exchange halted the economic growth which eventually led to the recession witnessed in 2016 in the country. The government realise it is likely for the economy to remain on the same path unless something is done to change the slope.

Agriculture has contributed to the GDP of Nigeria on a steady base, there was 4.88% growth in the sector in the middle of 2016, and had recorded 13% in the previous year, suggesting how huge this sector can contribute to the economy (Ministry of budget & National Planning 2017). Increase in investment in the agricultural sector can boost food security, creates employment and to a significant extent help to improve the foreign exchange by exporting the agricultural products. The contribution of agriculture to the growth of the economy can be view in the way of providing food for the exploding population of the country, increasing the demand of industrial products, providing foreign exchange for imported goods, creating employment for the growing population, and improving the welfare of rural people. The growth in the agricultural sector could be could an upward projection for national output growth through its effects in rural income and provision of resources for industrialization.

Although small scale farmers dominate agricultural production in Nigeria and individually exert little influence, collectively they form the foundation upon which the economy rests. About 90 percent of Nigeria's total food production comes from small farms and at least 60 percent of the country's population earns their living from these small farms with farm sizes less than 2 hectares (Oluwatayo et al., 2008). Unfortunately, these small-scale farmers are subsistence farmers and use crude and traditional production techniques. This has contributed to the deficient performance of the sector. Therefore, effective economic development strategy will depend critically on promoting productivity and output growth, particularly among small-scale producers since they make up the bulk of the nation's agriculture.

Nigeria has 70.8 million hectares of agriculture land area with maize, cassava, guinea corn, yam beans, millet and rice being the major crops. Nigeria's rice production rose from 3.7 million metric tons in 2017 to 4.0 million metric tons in 2018. Inspite of this, only 57percent of the 6.7 million metric tons of rice consumed in Nigeria annually is locally produced leading to a deficit of about 3 million metric tons, which is either imported or smuggled into the country illegally. To stimulate local production, the Government banned importation of rice in 2019 (FAO., 2020).

Animal production has remained underexploited. Livestock mostly reared by farm families in Nigeria are the small ruminants like goats (76 million), sheep (43.4million), and cattle (18.4 million). The ecology in the northern part of the country makes it famous for livestock keeping. In addition to small and large ruminants, poultry population stands at 180 million poultry (FMARD, 2017). Here too domestic demand outweighs production despite several interventions by development partners to improve production and safeguard against diseases including transboundary animal diseases.

3.4 Indicators of Climate Change on Agricultural System

The indicators of climate change are those vital systems/organisms which alter in response to the change in environmental conditions (Ganesh, 2021). The OECD defines the indicators as

> "*a parameter, or a value derived from parameters, which points to/provides information about/describes the state of a phenomenon/environment/area with a significance extending beyond that directly associated with a parameter value.*"

Therefore, indicators on climate change provide valuable information on the phenomenon that are critical to environmental quality, which simplify the complex reality (Walshe and Stancioff, 2018).

The primary purpose of the climate change indicators is to provide information on climatic conditions as an early warning system based on available observational data that points towards the environmental problem and help to address those problems before it gets worse (Anderson et al., 2017). Agricultural productivity is extremely sensitive to climate and weather conditions. Agricultural management decisions and productivity are influenced by variables like soil moisture, temperature, pest pressure, precipitation, growing season length and timing of frost (Ganesh, 2021). The productivity of agriculture is closely tied with local environmental conditions therefore the effects differ from place to place and can even exacerbate the existing stresses in the food system (Ko et al., 2012). The change in physical variables such as precipitation and temperature can influence many aspects of the agricultural system, production and management that includes agriculture workforce, crops, market price, management practices and natural resources such as water and soil (Ko et al., 2012). Precipitation is the main source of water for agriculture therefore understanding the projected changes and trends, amount, timing, and seasonality is crucial to the sustainable productivity of agriculture (Hartter et al., 2012). Another indicator is soil moisture, an integrator of many climatic impacts on the agricultural system. Therefore, changes in soil moisture impact crop production (Grillakis, 2019).

Increases in atmospheric temperature are projected, increasing the very warm nights and days (USGCRP, 2018). The increase in high night time temperature can seriously affect the human health and agricultural system, especially on grains and vegetables production (Wolfe et al., 2018). This has an adverse impact during reproduction, fertilization, flowering, pollination and in various stages of development (Hatfeld and Prueger, 2015).

Similarly, increase in the heat stress is associated with drought, humidity that shows an impact on plant productivity in the agricultural system (Fahad et al., 2017). Increase in temperature favours the weeds, leading to the greatest control cost and direct economic loss in crop production (Ramesh et al., 2017). The distribution and development of insects are influenced by climate change. Shifting precipitation and increasing temperature patterns are expanding the range and incidence of some insects in agricultural production (USGCRP, 2018). The research on the plant diseases led by climate change indicates that climate change can alter many aspects of pathogens' biology, including spatial distribution, disease development, plant pathogen interaction, and host resistance (Elad and Pertot, 2014).

3.5 Impacts of Climate Change on Agriculture

The increase in 100-110% crop production and additional 2.7-4.9 million hectare of land is needed by 2050 to feed the global population (Kontgis et al., 2019). While the climate variability is a crucial factor that influences farmers income and food production (Wheeler and Barun, 2013). Climate change influences the magnitude and durability of heat and water stress, which directly impacts the agricultural system (Lobell, et al., 2015). Climate change can also affect natural resources especially the water and land which are important aspects of agricultural production (UN-Water, 2013).

For instance, there is a rapid decline in the groundwater table in India due to the growing reliance of farmers on groundwater to adapt to the drought induced by climate change (Fishman, 2018).

Annual increase in average maximum temperature in South Asia could increase the heat stress by 12% in 2030 and 21% in 2050 which can have the unexpected consequences on cereals production (Pask et al., 2014). There will be greater fluctuation in food supplies, crop production and market price that will aggravate the poverty and food security affecting millions of people (Luan et al., 2013). Therefore, Climate change has already influenced agricultural productivity and has threatened food security as well as livelihoods of farmers worldwide.

Poor and vulnerable people dependent on agriculture should be appropriately addressed in research and development activities (Westermann et al., 2018). The variables of climate change like temperature, radiation and rainfall are important parameters for crop productivity in unusual ways. The increase in temperature beyond 3ºC is likely to have negative consequences worldwide in the agricultural sector, especially the impacts faced by the agricultural dependent countries (IPCC, 2014). The increase in temperature indirectly affects the yields of crops since it changes the biological and physical systems of the crops (Zhao et al., 2017). The change in climatic patterns like precipitation, storms, and heat stress can make the crops respond to the change and are likely to negatively affect production (Ahmed et al., 2019).

The change can also increase abiotic and biotic stress that forces the agricultural system to change differently. This can seriously impact production and food security (Zandalinas et al, 2021).

Previous studies on climate change and vulnerability show that the change will influence current and future food systems and farming methods due to the modification and shifts in seasons and the water cycle (Fanzo, 2018). The input side is likely to be affected by the change in fertilization pattern, recollection of land and alteration of agricultural water use that can affect the agricultural output unexpectedly (Guo et al., 2020). Using the integrated assessment and historic data, many studies show the decline in the annual crop yield due to the change in the weather pattern (Deryng et al., 2014).

3.5.1 Impacts of Climate Change on Animal Production

Livestock production is potentially sensitive to climate change. Climate affects animal production in four ways: livestock feed-grain availability and price; impacts on livestock pastures and forage crop production and quality; changes in the distribution of livestock diseases and pests; and the direct effects of weather and extreme events on animal health, growth, and reproduction (Henry et al., 2012). The impact of climate change on pastures and rangelands includes deterioration of quality subtropical grasses in temperate regions because of warmer temperatures and less frost therefore, productivity of grazing livestock could be altered (Morgan, 2019).

The author further stated that alterations of temperature and precipitation regimes results in a spread of disease and parasites into new regions or produce an increase in the incidence of disease, which, in turn, would reduce animal productivity and increase animal mortality. Under hot temperature conditions, the inability of animals to dissipate environmental heat results to heat stress especially during hot seasons. There is a range of thermal conditions within which various animals can maintain a stable body temperature.

Heat stress results from the animal’s inability to dissipate sufficient heat to regulate body temperature (Daramola et al., 2012). Thus, an increase in air temperature, such as that expected in different climate change scenarios, would directly affect animals' performance by upsetting their heat balance.

3.5.2 Impacts of Climate Change on Crop Production

Crops need nutrients, water, and heat to drive the photosynthetic process and produce edible products. Water and heat are factors affected by climate, but so are nutrients. Increased CO_2 concentrations can be beneficial to crop productivity; but changes in temperature and precipitation can have mixed results, compounded by the high sensitivity of crops to extreme events such as floods, wind storms and droughts, and seasonal factors such as periods of frost, heat spells, and change in rainfall patterns (Walthall et al., 2013). Crops are often more sensitive to averages than extreme temperature, as yields gradually rise to a temperature threshold and then collapse rapidly as temperatures increase above the threshold (Ackerman and Stanton, 2013). It is obvious that most crops have an optimum temperature, at which their yields per hectare are greater than either higher or lower temperatures. Many crops are known to have temperature thresholds and varying temperatures for various stages of growth.

Changes in climate could have significant impacts on crop productions around the world. Negative impacts are expected for a few crops in developing countries by, 2030 (Wiebe et al., 2019). Temperature effects on cereals’ (like maize and wheat) and legumes’ (such as soybean) yields in the United States are strongly asymmetric, with optimum temperatures of 29 - 32°C resulting to rapid drops in yields for days (IPCC, 2014).

According to the author, in maize production, replacing 24 hours of the growing season at 29°C with 24 hours at 40°C caused a 7% decline in yields. A remarkably similar pattern was found in a study of temperature effects on maize yields in Africa, with a threshold of 30°C (Lobell et al., 2008). Under ordinary conditions, the effects of temperature above the threshold on yields were like those found in the United States; under drought conditions, yields declined faster with temperature increase. Limited production output of wheat in northern India also suggests that temperature increase above 34°C becomes more harmful (Lobell et al., 2012). The author further stated that by mid-century, under the current climate scenario, yields are projected to drop by 17 to 22 % for maize, sorghum, millet, and groundnuts (peanuts) and by 8 % for cassava. Among the crops most vulnerable to temperature increases are millet, groundnut, and rapeseed in South Asia; sorghum in the Sahel; and maize in southern Africa (Lobell et al., 2011).

In Nigeria, crop production is expected to be affected drastically, due to climate influences leading to ecological degradation. In Nigeria, as at 2011, agriculture contributed about 40.19% (crop; 35.78%, livestock; 2.58, forestry; 0.51%, fishing; 1.32%) to GDP and in 2012 its contribution declined to 39.19% (crop; 34.83%, livestock; 2.55 %, forestry; 0.50%, fishing; 1.31%) (Eagles, 2014). From the above data, crop production contribution dropped from 35.78% in 2011 to 34.83% in 2012 which can be attributed to the ravaging impacts of climate change in the various cultivation states of the country.

3.5.3 Impacts of Climate Change on Fishing/Fish Farming

The world's fisheries provide more than 2.6 billion people with at least 20% of their average annual per capita protein intake (Searchinger et al., 2019).

In the high CO_2 world, it is considered that ocean temperature will rise, currents 81 will spin-up, acidification will occur, sea ice will decrease, area of oligotrophic gyres will increase, and seasonality of biological productivity will change which poses adverse effects on marine fish species include their reproduction, ecological connectivity, and biodiversity (Doney et al., 2012). Other changes in oceans, lakes and rivers impacting on aquatic ecosystems and fish population include increased salinity, alteration in density and stratification, sea, lake, and river levels sedimentation brought about by climate-induced variation in land use. In turn, these physical alterations have the potential of changing the physiological, spawning and growth processes of aquatic lives such as fish, affect primary (e.g., diatoms and phytoplankton) and secondary (e.g. zooplankton) producers, distributions of fish (through permanent movement, or changes to migration patterns), the abundance of fish (due to changes in primary and secondary producers), phenology (e.g. timing of life-cycle evens such as spawning), species and disease invasions and other food web impacts (Poloczanska et al., 2016).

Climate change has affected fisheries through alterations in potential catch due to shifts in species' range and decline in primary prey available to the species caused by acidification of the oceans from higher CO_2 levels, loss of coral reefs because of ocean warming, and variations in ocean biogeochemistry, such as oxygen levels (Doney et al., 2012). Shifting distributions of fish have led to series of international disagreements and will continue to have implications for fisheries management across international water boundaries (Cheung et al., 2012).

In small Islands, deterioration in coastal conditions, such as beach erosion and coral bleaching, has affected local resources such as fisheries, as well as the value of tourism destinations (Barbier et al., 2011). The effect of drought leads to streams, ponds and wells drying up causing a sharp decline in fish population around the world (Vicente-Serrano, 2020).

3.6 Climate Change Impacts on Food Security

Sub-Saharan Africa is particularly vulnerable to the negative effects posed by climate change. In the Horn of Africa, droughts have become increasingly severe over the past decade, with rainfall totals at least 50-75% below average in the area. Furthermore, this region of Africa is predicted to experience an increase in temperatures of approximately 1.5 times compared to that of the mean global average by the end of the 21st century (Bryan et al., 2013). Meteorological droughts (resulting from insufficient rainfall) are expected to increase in duration, frequency and intensity attributed to climate variability and change (Shiru et al., 2019).

Climate change is expected to affect food security due to dependence on rain-fed agriculture, prominent levels of poverty, and low levels of human and physical capital. According to the IPCC fifth assessment report, the major crops grown in Sub-Saharan Africa are extremely sensitive to temperature, with estimated yield losses of 22% by 2050 (IPCC, 2014). Climate variability and extreme weather events such as droughts and excessive rains and floods affect agricultural productivity when the rainy season fails to reduce food availability at the household level and limit future rural employment opportunities (Thornton and Lipper, 2014).

Additionally, decreases in food availability are predicted to decline by 20% per person in, 2050 and the number of malnourished children in sub-Saharan Africa is expected to increase by 52 million by 2050 (Lloyd et al., 2011). This is especially problematic in the context of population growth. For example, in Africa alone, 650 million people are dependent on rainfed agriculture in environments that are affected by water scarcity, land degradation, recurrent droughts and floods, and this trend is expected to exacerbate under climate change and population growth (Adeniyi, 2016). Climate change will act as a hunger risk multiplier exacerbating current vulnerabilities and could affect all dimensions of food security in complex ways (Schnitter and Berry, 2019).

4. Methodology

4.1 Study area

The study area is Nigeria, characterized by three distinct climate zones, a tropical monsoon climate in the south, a tropical savannah climate for most of the central regions, and a Sahelian hot and semi-arid climate in the north of the country. This leads to a gradient of declining precipitation amounts from south to north. The southern regions experience strong rainfall events during the rainy season from March to October with annual rainfall amounts, usually above 2,000 mm, and can reach 4,000 mm and more in the Niger Delta (Shiru et al., 2019).

The central regions are governed by a well-defined single rainy season (April to September) and dry season (December to March). The Harmattan wind from the Sahara influences the dry season. Coastal areas experience a short drier season with most rain occurring over March to October. Annual rainfall can reach up to about 1200 mm. In the north, rain only falls from June to September in the range of 500 mm to 750 mm. The rest of the year is hot and dry. Northern areas have a high degree of annual variation in their rainfall regime, resulting in flooding and droughts.

The most significant temperature difference in Nigeria is between the coastal areas and its interior as well as between the plateau and the lowlands. On the plateau, the mean annual temperature varies between 21°C and 27°C whereas in the interior lowlands, temperatures are over 27°C. The coastal fringes have lower means than the interior lowlands. Seasonal mean temperatures are consistently over 20℃ throughout the country and diurnal variations are more pronounced than seasonal ones. Highest temperatures occur during the dry season and vary little from the coast to inland areas.

Like rainfall, the relative humidity in Nigeria decreases from the south to the north, with an annual mean of 88% around Lagos.

Nigeria's mean annual temperature is 26.9°C, with average monthly temperatures ranging between 24°C (December, January) and 30°C (April). Mean annual precipitation is 1,165.0 mm. Rainfall is experienced throughout the year in Nigeria, with most significant rainfall occurring from April to October and with minimal rainfall occurring November to March.

4.2 Data source

The data used were obtained from the Food and Agricultural Organization (FAO), and The World Bank database. Time series data of climate (rainfall and temperature) and agricultural productions in Nigeria over a period of 20 years (1999 – 2018) was used for this study. The agricultural production data include data on crops yield (cassava and maize) and livestock production (chicken and goat) in Nigeria. Cassava is one of the main staple foods in Sub-Saharan Africa, one of the two most important staples in Nigeria, providing at least one-third of the calorie intake and a much larger share among the poor (De Souza et al., 2016). Maize is one of the important grains in Nigeria, not only based on the number of farmers that engaged in its cultivation, but also in its economic value. Maize is a major important cereal crop being cultivated in the rainforest and the derived savannah zones of Nigeria. Goats are kept by smallholder farmers in Nigeria for meat, hides, wool and, to a lesser extent, milk while chickens play a significant role for the rural poor and marginalised section of the people with respect to their subsidiary income and provide them with nutritious chicken egg and meat for their own consumption.

4.3 Data analysis

Descriptive statistics, Mann-Kendall's trend test, and Pearson correlation were used to analyse the data using Microsoft Excel and Statistical Package for Social Sciences (SPSS) version 26.

4.3.1 Mann-Kendall's trend test

The Mann-Kendall (MK) test (Mann 1945, Kendall 1975) aims to factually evaluate if there is an upward or descending pattern of the variable of interest after some time. A monotonic upward (descending) slant implies that the variable reliably expands (diminishes) through time, yet the pattern could be straight. The MK test can be utilized as a part of place of a parametric linear regression analysis, which can be utilized to test if the slop of the estimated linear regression line is different from zero. The regression examination requires that the residuals from the fitted regression line be normally distributed; an assumption not required by the MK test, that is, the MK test is a non-parametric (dispersion free) test.

4.3.2 Pearson Correlation

Correlation analysis is a statistic technique which aims to find relationship with correlation degree between two variables (Zawawi, 2012). Correlation studies are concerned with determining the extent of relationship between variables. They enable one to measure the extent to which variations in one variable are associated with variations in determined with the correlation coefficient. There are three results of correlational study: a positive correlation, a negative correlation, and no correlation.

According to Nunan (1992), the correlational coefficient is a measure of correlation strength and can range from -1.00 to 1.00. Perfect positive correlation would result in a score of 1. Perfect negative correlation would result in -1.

5. Results and Discussion

5.1 Variability in climate parameters in Nigeria

5.1.1 Variability in Rainfall

The trend observed in annual rainfall amounts for the period 1999 to 2018 in Nigeria is presented in Table 1 and Figure 1. The result revealed a decreasing trend with a negative Kendall's tau value of -0.02. The annual rainfall amounts received in Nigeria between 1999 – 2018 varied from 1027mm to 1251mm, averaging 1151mm. A linear trend tilted on the data shows that the decrease is not strong ($R^2 < 0.028$) and is insignificant ($P=0.92$).

The trend observed in annual rainfall amounts in Nigeria between 1999 to 2018 is decreasing. A statistical analysis found that the decrease was insignificant but depicted a high standard deviation, implying that the area is currently contending more with rainfall variability than change. Rainfall amount and timing can influence the yield of crops. Low rainfall amounts can be detrimental to crop yield, especially if the dry periods occur during critical developmental stages (Fosu-Mensah, 2013). Erratic rainfall pattern can also activate severe climatic events including droughts and floods, which can have unfavourable impacts on the yields of food crops (Rahman et al., 2017). This finding is in line with findings by Some and Kone, (2000) in West Africa. Similarly, Worishima and Akasaka (2010) reported that rainfall in southern Africa and parts of the Horn of Africa is decreasing. However, most studies have found out an increasing trend of rainfall (Cynthia et al., 2002; IPCC, 2007; Schmidhuber and Tubiellos, 2007; Alexander, 2013).

5.1.2 Variability in Average Temperature

The trend analysis of average temperature for the period 1999 to 2018 in Nigeria is shown in Table 1 and Figure 2. A visual inspection into the average temperature graph reveals that average temperatures have been oscillating in an increasing progression indicating increasing trend for the two decades The result revealed an increasing trend with Kendall's tau value of 0.39. The annual average temperature in Nigeria between 1999 – 2018 varied from 26.85^{0}C – 27.81^{0}C averaging to 27.35^{0}C. A linear trend tilted on the graph shows that the increase is not strong (R^2<0.028) but significant (P=0.02) (Figure 2).

5.1.3 Variability in Minimum Temperature

The trend of annual minimum temperature for the period 1999-2018 is illustrated in Figure 3. The minimum temperature also increased linearly with time. It varied from 20.71^{0}C to 21.71^{0}C averaging to 21.41^{0}C and statistical analysis reveals that the increase was statistically strong (R^2>0.5) and significant ($p<0.05$) with Kendall's tau value of 0.59 (Table 1). A visual inspection into the temperature minimum graph for the period 1999 – 2018 revealed that minimum temperatures have been varying in an increasing progression indicating increasing regime for the two decades.

Table 1: Trend Analysis of Climate variability in Nigeria between 1999 –2018

Variable	Minimum	Maximum	Mean	Std Deviation	Kendall's tau	p-value
Rainfall (mm)	1027.38	1251.17	1151.27	63.76	-0.02	0.92
Average Temp (^{0}C)	26.85	27.81	27.35	0.24	0.39	0.02
Temp (Min) (^{0}C)	20.71	21.89	21.41	0.30	0.59	0.00
Temp (Max) (^{0}C)	33.02	33.78	33.34	0.22	0.23	0.17

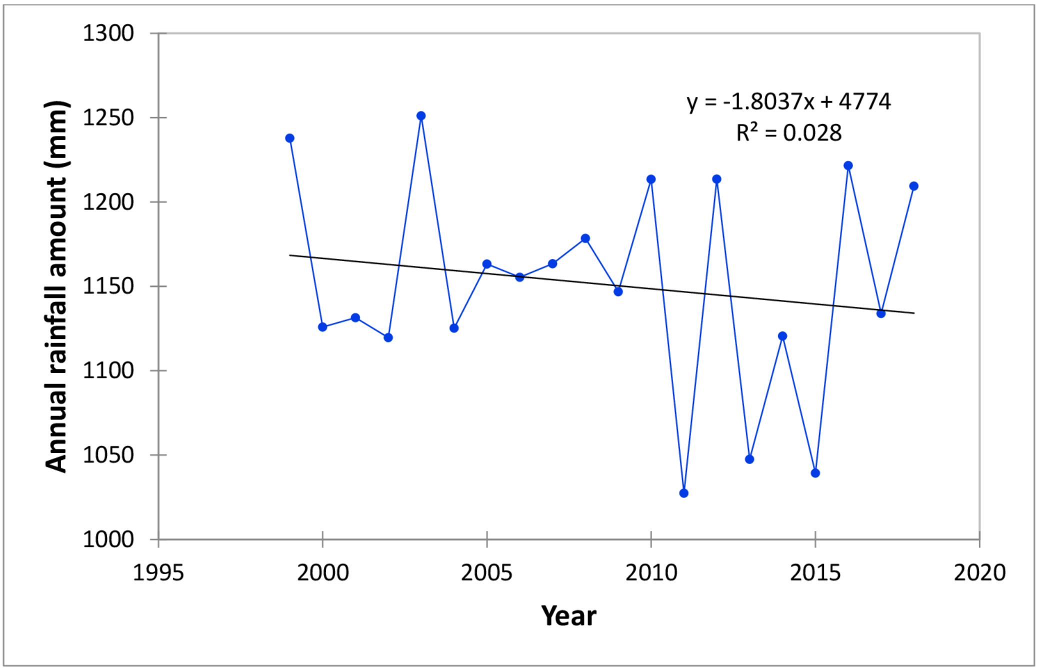

Figure 1: Annual rainfall amount (mm) trend in Nigeria between 1999 – 2018

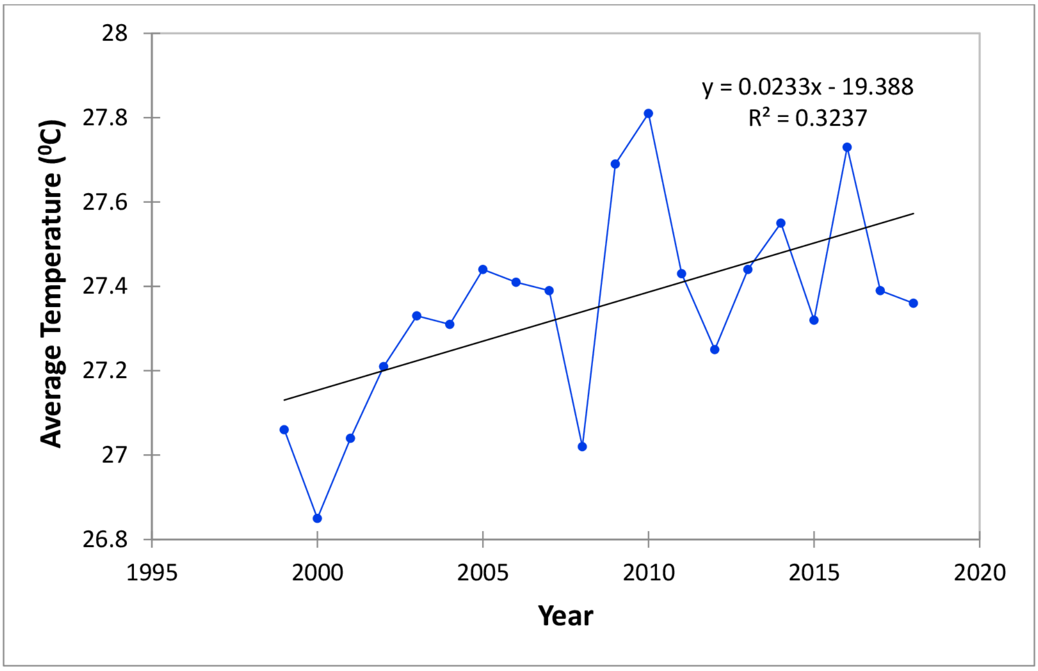

Figure 2: Average temperature (^{0}C) trend in Nigeria between 1999 – 2018

5.1.4 Variability in Maximum Temperature

The mean annual maximum temperature trend in Nigeria for the period 1999 – 2018 is illustrated in Figure 4. The area experiences a linear increase in annual maximum temperatures which is weak ($R^2 < 0.5$) and insignificant ($P>0.05$). It ranged from 33.02^{0}C to 33.78^{0}C, averaging to 33.34^{0}C with Kendall's tau value of 0.23 (Table 1). A visual inspection into the maximum temperature graph reveals that maximum temperatures have been oscillating in an increasing progression indicating increasing trend for the two decades.

The result of this study revealed that the minimum temperature increased rapidly than the average temperature and the maximum temperature. This was explained by a higher percentage (51.1%) of the observed variance in the minimum ($R^2 = 0.511$) than that observed of (32.3%) in the average temperature ($R^2 = 0.323$) and 7.9% in the maximum temperature ($R^2 = 0.079$). Based on these results, it is noted that over the period under study (1999 – 2018), the minimum temperature in Nigeria has increased rapidly than the average temperature and maximum temperature. This has an implication on the increase of hot days as compared to cold ones. These results concur with those by IPCC (2014), which reports on the increase of the global temperature that has also resulted to the increase in temperature at local levels. The results are also in line with what was reported by Aondoakaa (2012) in Nigeria, Ashalatha et al. (2012) and Sivakumar et al. (2005) in India, Malik et al. (2012) in Pakistan, Sarr (2012) in dry land areas of West Africa, Bryan et al. (2009) in Ethiopia and South Africa, Owusu-Sekyere et al. (2011) and Owusu (2009) in Ghana, Kangalawe and Lyimo (2013), Lyimo and Kangalawe (2010) as well as Lema and Majule (2009) in Tanzania who also reported on increased trends in temperature.

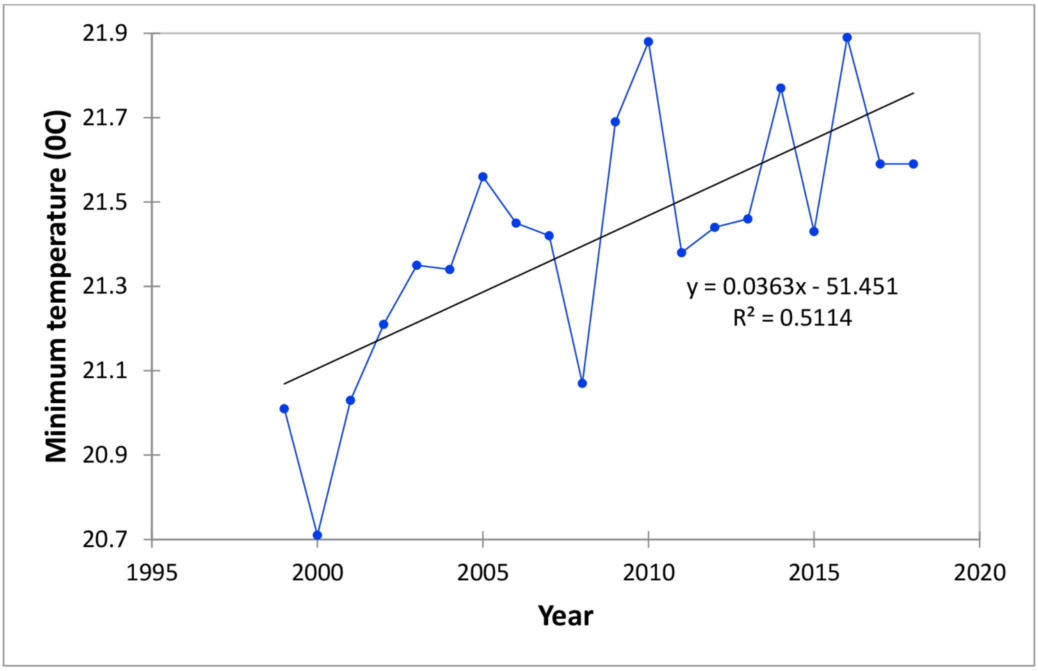

Figure 3: Minimum temperature (^{0}C) trend in Nigeria between 1999 – 2018

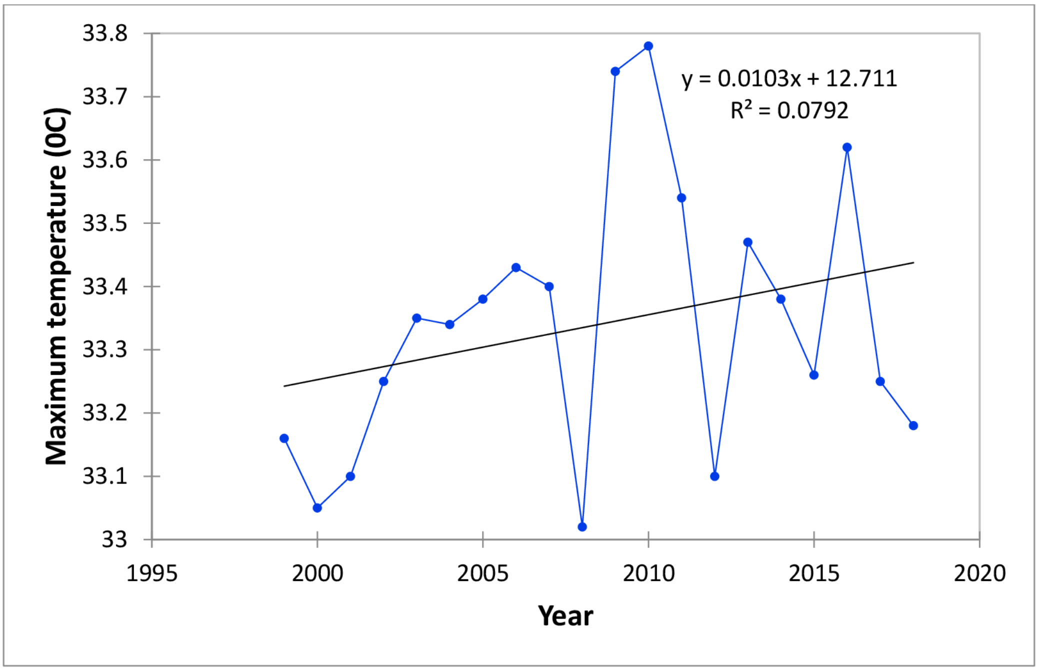

Figure 4: Maximum temperature (^{0}C) trend in Nigeria between 1999 – 2018

5.2 Variability in Agricultural Production in Nigeria

5.2.1 Variability in Cassava Yield (ton/ha)

The trend of cassava yield in Nigeria for the period 1999 – 2018 is presented in Figure 5. The result revealed a decrease in cassava yield which is statistically weak ($R^2<0.5$) and insignificant ($P>0.05$). It ranged between 7.03 to 12.21 (ton/ha) averaging to 10.04ton/ha with Kendall's tau value of -0.147 (Table 2). A visual inspection into the cassava yield graph reveals that the cassava yield has been oscillating in a decreasing progression, indicating a downward trend for the two decades.

5.2.2 Variability in Maize Yield (ton/ha)

The trend of maize yield for the period 1999-2018 in Nigeria is illustrated in Figure 6. The maize yield also decreased linearly with time. It varied between 1.3 to 2.2 ton/ha averaging to 1.63 ton/ha and statistical analysis reveals that the decrease was statistically weak ($R^2>0.5$) and insignificant ($p>0.05$) with Kendall's tau value of 0.17 (Table 2). A visual inspection into the maize yield graph for the period 1999 – 2018 revealed that maize yield has been varying in a decreasing progression indicating decreasing regime for the two decades.

Table 2: Trend Analysis of Agricultural Production in Nigeria between 1999 – 2018

Variable	Min	Max	Mean	Std Deviation	Kendall's tau	p-value
Cassava yield (ton/ha)	7.03	12.22	10.04	1.48	-0.15	>0.05
Maize yield (ton/ha)	1.30	2.20	1.63	0.20	0.17	>0.05
Goats (million)	40.00	80.25	58.77	13.01	1	<0.001
Chicken (million)	113.20	192.31	152.82	22.60	0.51	0.002

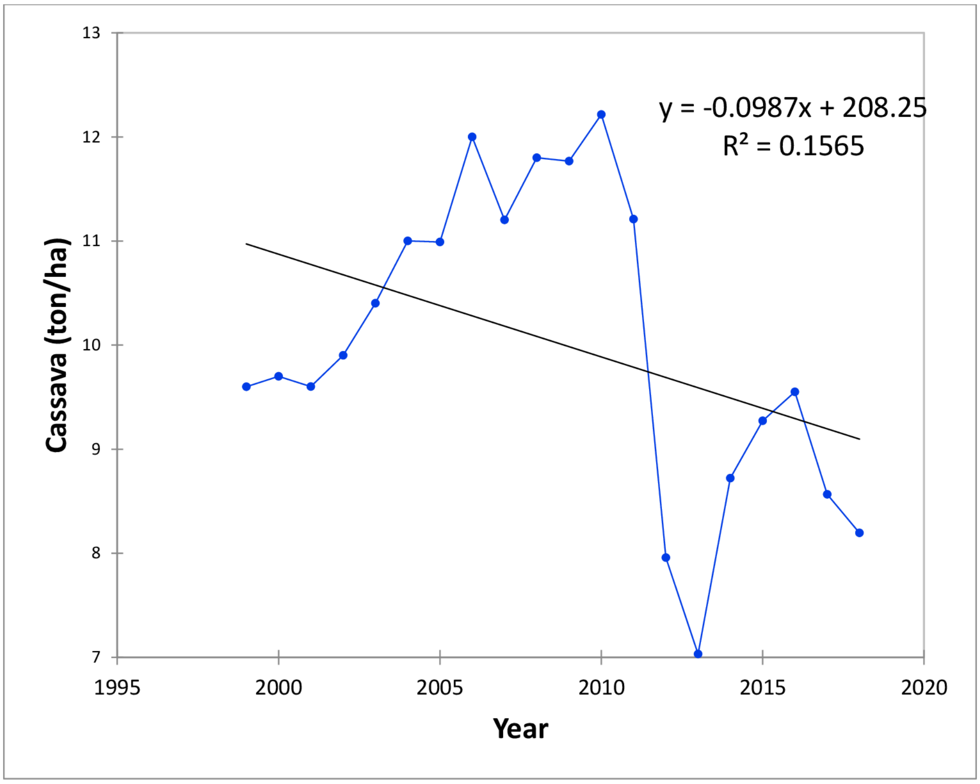

Figure 5: Cassava yield (ton/ha) trend in Nigeria between 1999 – 2018

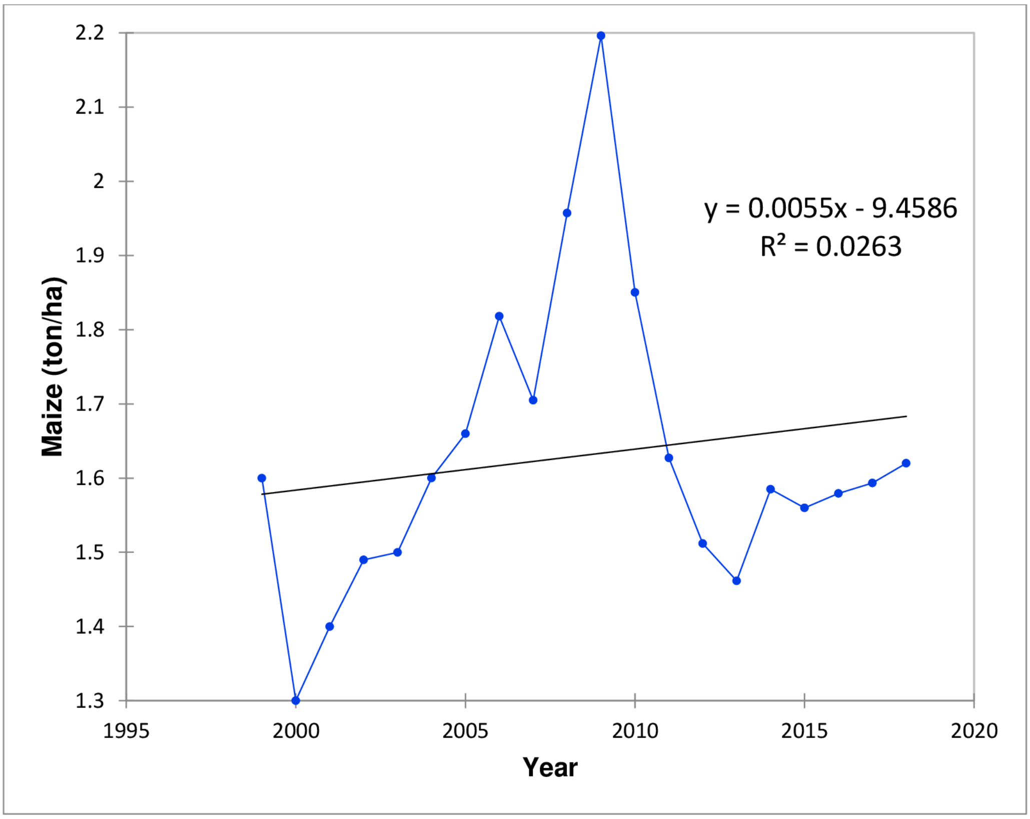

Figure 6: Maize yield (ton/ha) trend in Nigeria between 1999 – 2018

5.2.3 Variability in Goats Production

The trend observed in goat production for the period 1999 to 2018 in Nigeria is presented in Table 2 and Figure 7. The result revealed an increasing trend with Kendall's tau value of 1. The goat's production recorded in Nigeria between 1999 – 2018 varied from 40.00 – 80.25 million averaging to 58.77 million. A linear trend tilted on the graph shows that the increase is statistically strong (R^2> 0.96) and significant (P<0.0001).

5.2.4 Variability in Chicken Production

The trend of chicken production in Nigeria for the period 1999 – 2018 is presented in Figure 8. The result revealed an increase in chicken production which is statistically weak (R^2<0.5) but significant (P<0.01). It ranged between 113.2 million to 192.31 million averaging to 152.82 million with Kendall's tau value of 0.51 (Table 2). A visual inspection into the chicken production graph reveals that chicken production has been oscillating in an increasing progression, indicating an uptrend for the two decades.

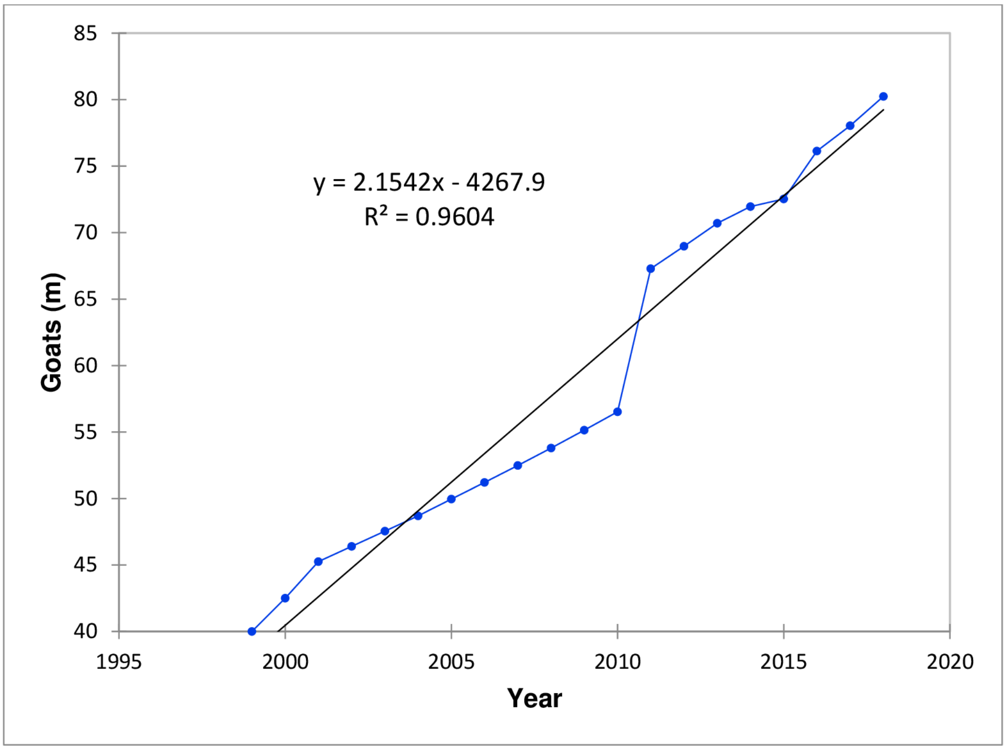

Figure 7: Goat production trend in Nigeria between 1999 – 2018

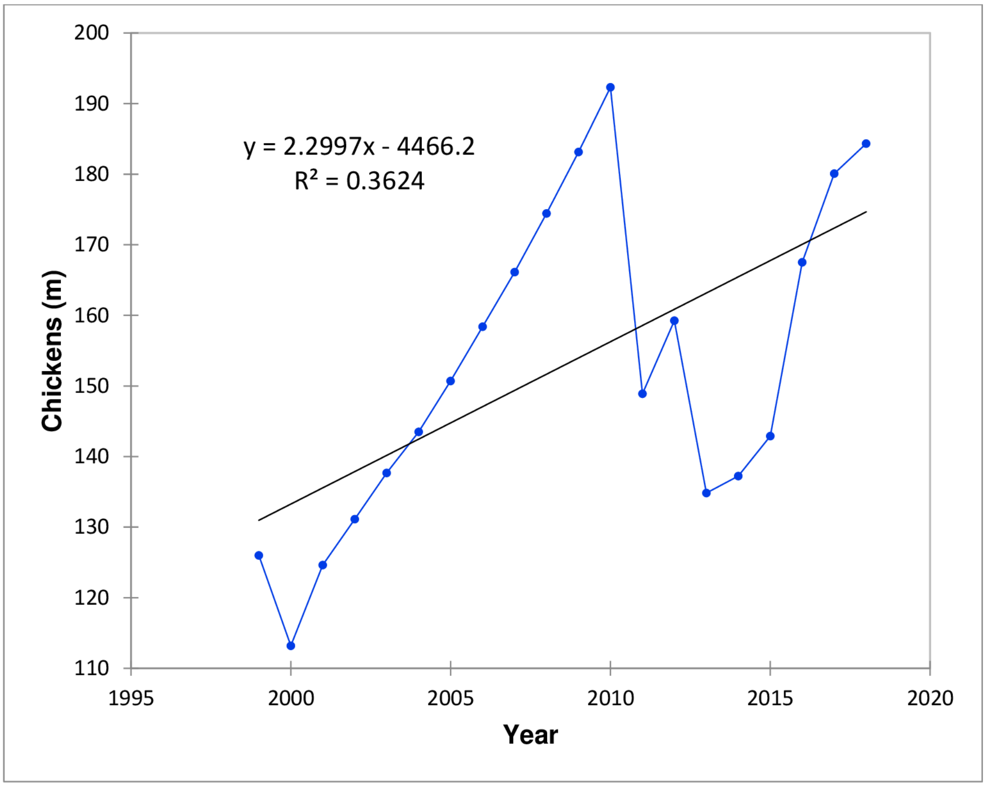

Figure 8: Chicken production trend in Nigeria between 1999 – 2018

5.3 Relationship between Climate Trend and Agricultural Production

The result of the relationships among climate variables and agricultural production in Nigeria as assessed using Pearson’s correlation, is presented in Table 3. There were insignificant positive relationships between the average annual rainfall (mm) and cassava yield (0.141, $p>0.05$), maize yield (0.165, $p>0.05$), and chickens (0.309, $p>0.05$). However, the relationship between average annual rainfall and goats was negative and insignificant at $p<0.05$ (-0.213). The relationships among temperature variables and agricultural production variables were positive. Significant positive association was recorded among average temperature and maize yield (0.474, $p<0.05$), goats' production (0.477, $p<0.05$), and chickens' production (0.613, $p<0.01$). However, the positive relationship between average temperature and cassava yield was not significant (0.176, $p>0.05$). Significant positive relationships were also observed among minimum temperature and goats' production (0.0.636, $p<0.01$) and chickens' production (0.636, $p<0.01$). Meanwhile, the positive relationships exist between minimum temperature and cassava yield (0.011) as well as maize yield (0,408) but not significant ($p>0.05$). Maximum temperature was also positively correlated with all agricultural production variables, but the relationships were not statistically significant at $p<0.05$ apart from maize yield (0.495, $p<0.05$).

Table 3: Pearson correlation of climate variables and agricultural production

	Rainfall (mm)	Average Temp (^{0}C)	Temp (Min) (^{0}C)	Temp (Max) (^{0}C)
Cassava yield (ton/ha)	0.141	0.176	0.011	0.382
Maize yield (ton/ha)	0.165	0.474*	0.408	0.495*
Goats (million)	-0.213	0.477*	0.636**	0.188
Chickens (million)	0.309	0.613**	0.668**	0.440

* Correlation is significant at the 0.05 level (2-tailed).

** Correlation is significant at the 0.01 level (2-tailed).

6. Conclusion and Recommendations

6.1 Conclusion

The research investigated Nigeria's climate characteristics and agricultural production based on secondary data obtained from FAOSTAT and World Bank. Findings on rainfall analysis have indicated insignificant decreasing trends in Nigeria. The overall objective of the study was to assess the effect of climatic variability on agricultural production in Nigeria.

The objective 1 was to explore the trend in climate variation in Nigeria over a period of two decades. Temperature trend analysis has shown significant increased trends for average annual, maximum, and minimum temperatures. For any crop, the effect of increased temperature will depend on the crop's optimal temperature for growth and reproduction. In some areas, warming may benefit the types of crops that are typically planted there or allow farmers to shift to crops that are currently grown in warmer areas. Conversely, if the higher temperature exceeds a crop's optimum temperature, yields will decline.

The objective 2 was to assess the trend in agricultural production in Nigeria over a period of two decades. Agricultural production in Nigeria also revealed significant increased trends for the study period in Nigeria. Agricultural production in Nigeria has been oscillating in an increasing progression, indicating an increasing trend for the two decades under study. This may be because of increased government interventions in the agricultural sector of the country.

The objective 3, Identify the relationship between climate variability and agricultural production in Nigeria over a period of two decades. This study established significant positive relationship among temperature variables and agricultural production variables. The result of this study revealed that increased temperature and decreased precipitation over time in Nigeria have significant effect on crop yields and livestock production which are projected to increase under climate change and could directly threaten livestock. Drought may threaten pasture and feed supplies. Drought reduces the amount of quality forage available to grazing livestock. Some areas could experience longer, more intense droughts, resulting from higher summer temperatures and reduced precipitation. For animals that rely on grain, changes in crop production due to drought could also become a problem. Climate change may increase the prevalence of parasites and diseases that affect livestock. The earlier onset of rainy season and dry season could allow some parasites and pathogens to survive more easily.

6.2 Recommendations

From the findings of this study, the following recommendations were made

1. The observed increased temperature and declined rainfall require adaptation strategies than usual to reduce adverse effects as climate variability increases.
2. Diversified coping and adaptation mechanisms should be undertaken.
3. Researchers need to come out with better and new crop varieties and livestock breeds that can survive under changed climate conditions.
4. Agricultural Institutions such as Agricultural Development agencies need to be strengthened to enhance adaptation to climate variability and change.

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