**Rainfall Variability and its effect on Livestock Production across Nigeria**


## Abstract

This study aimed at investigating climate variability and its impact on livestock production across Nigeria. Observational data of monthly rainfall was obtained for a period of 42 years (1979 to 2021) from Nigerian Meteorological Agency (NiMET). The yearly animal production data was also obtained for a period of 10 years (2013 to 2022) from Federal Ministry of Agriculture and Natural resources. The data obtained was subjected to descriptive statistical analysis (mean, standard deviation and coefficient of variation) to show spread and variability; linear regression to show trend (changes with time); coefficient of correlation to show statistical relationship between the variables (rainfall and each of the animal production); revealing insights into changing precipitation patterns. Positive and negative correlations were identified, indicating how changes in rainfall influenced livestock output. And the significance of these correlations was determined through t-tests, shedding light on the strength of the relationship between rainfall and livestock production.



**Keywords:** Nigeria; rainfall; variability; trend; livestock

## 1. Introduction

Climate change is the most severe predicament that the globe is facing recently. It has been recognized asgraver than global terrorism (Rao *et al*., 2011). Climate change affects food and water resources that are critical for livelihood in developing countries where much of the population rely on local supply systems that are sensitive to climate variability (Porter and Semenov, 2005). African farmers depend on livestock for income, food and animal products. Climate can affect livestock both directly and indirectly. Direct effects of climate variables such as air, temperature, humidity, wind speed and other climate factors influence animal performance such as growth, milk production, wool production and reproduction (Haines *et al*., 2006). Climate can also affect the quantity and quality of feedstuffs such as pasture, forage, and grain and the severity and distribution of livestock diseases and parasite. Hence, the totality of agricultural sector is considered by examining agricultural productivity (Zillock et al., 2015). The nation's natural and agricultural ecosystems, including freshwater and coastal resources, are highly susceptible to the effects of climate change (Ncube *et al*., 2012).

Rainfall is by far the most important element of climate change in Nigeria and its water resources potential (Weaver *et al*., 2013). Agriculture in Nigeria is mostly rain-fed, it follows therefore that any change in climate is bound to influence agricultural productivity and livestock production in particular and other socio-economic activities. The issue of climate change has become more threatening not only to the sustainable development of socio-economic and agricultural activities of any nation but also to the totality of human existence (Ncube *et al*., 2012).The most important systems responsible for Nigeria's rainfall are the Inter-Tropical Convergence Zone (ITCZ), the subtropical anticyclones and the monsoonal winds (Costello et al., 2009). Previous studies provide some evidence that a bimodal rainfall regime dominates the south of Nigeria, while a unimodal distribution is more apparent above 3° North (Zillock*et al*., 2015).Nigeria experiences varied rainfall, with some areas receiving heavy rainswhile other areas have experienced drought. In some seasons, there is early onset of the rain and late cessation while in other cases there is early onset of the rain and it stops when it is still expected to continue (Costello *et al*., 2009). The variability in distribution of rainfall arises from a series of interactions. Interannual variability of the rainfall has shown correlation with sea surface temperatures (SSTs) in the Pacific through atmospheric teleconnections and the ENSO phenomenon (Barnet et al., 2008).

Domestication and the use of conventional livestock breeding techniques have been largely responsible for the increases in yield of livestock products that have been observed over recent decades (Gwazaand Momoh, 2016). Considerable changes in the composition of livestock products have occurred (Rao *et al*., 2011). The nutritional needs of farm animals with respect to energy, protein, minerals and vitamins have long been known, and these have been refined in recent decades (Haines et al., 2006). Different countries have their different requirement determination systems for ruminants and non-ruminants, which were originally designed to assess the nutritional and productive consequences of different feeds for the animal once intake was known (Crespo et al., 2011; Weaver *et al*., 2013). Rapid population growth is an important impediment to achieving improvements in food security in most countries (Brown *et al*., 2012). Another important factor that determines the demand for food is urbanization

(Codjoe and Owusu, 2011). Urbanization has considerable impact on patterns of food consumption in general and on demand for livestock products in particular, urbanization often stimulates improvements in infrastructure, including cold chains, and this allows perishable goods to be traded more widely (Mohammed and Tarpley, 2009). Another driver leading to increased demand for livestock products is income growth. As income grows, so does expenditure on livestock products (Vermeulen *et al*., 2013). The last few decades have seen a general reduction in the burden of livestock diseases, as a result of more effective drugs and vaccines and improvements in diagnostic technologies and services (Ahmed et al., 2011).

This work aims at investigating rainfall variability and its effect on livestock production across Nigeria. The objectives of this study are to, (i) examine the trend in livestock production in Nigeria, (ii) investigate the trend and variability of rainfall across Nigeria from 1979 to 2021, and (iii) analyze the link between rainfall variability and livestock production in Nigeria.It is worth noting that numerous empirical studies on different aspects of livestock production in Nigeria have been carried out (Hellin et al., 2012). Despite the myriads of research in livestock, there exists a gap in livestock research with respect to livestock production and climate change nexus in Nigeria. The global trend in climate variability has necessitated this study to gain insight into the relationship between livestock production and rainfall variability in Nigeria (Thornton *et al*., 2011).

## 2. Materials and Methods

### 2.1 Study Area

Nigeria is located on the West Coast of Africa and is made up of about 223.8 million people as at mid 2023 (Vollset*et al*., 2023). It is bordering the North Atlantic Ocean, between Benin and Cameroon. It covers 923,770sq kilometers (Odusanya and Adekitan, 2019). Nigeria is characterized by three distinct climate zones, a tropical monsoon climate rain forest 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 (Ellis and Galvin, 2014). 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 (Adejuwon, 2018).

The rainy season is from April to September in the central region whereas the dry season is from December to March of the following year. The dry season is influenced by the harmattan wind from the Sahara (Vollset*et al*., 2023). The coastal areas experience shorter dry season (Odusanya and Adekitan, 2019). The country is influenced by the localized convection of the West African monsoon whereas the wet season rainfall starts in May and ends in October, with an annual minimum of 110 mm/yr along the northern savanna and maximum of 2600 mm/yr along the southern mangrove (Nwokocha *et al*., 2018). Northern areas have a high degree of annual variation in its rainfall regime, which results in flooding and droughts (Odusanya and Adekitan, 2019).

Mean annual temperature for Nigeria is 26.9°C, with average monthly temperatures ranging between 24°C (December, January) and 30°C (April). The predominant occupation of the citizens is agriculture, and the nature of agriculture popularly practiced is subsistence agriculture (Dankumo*et al*., 2015).

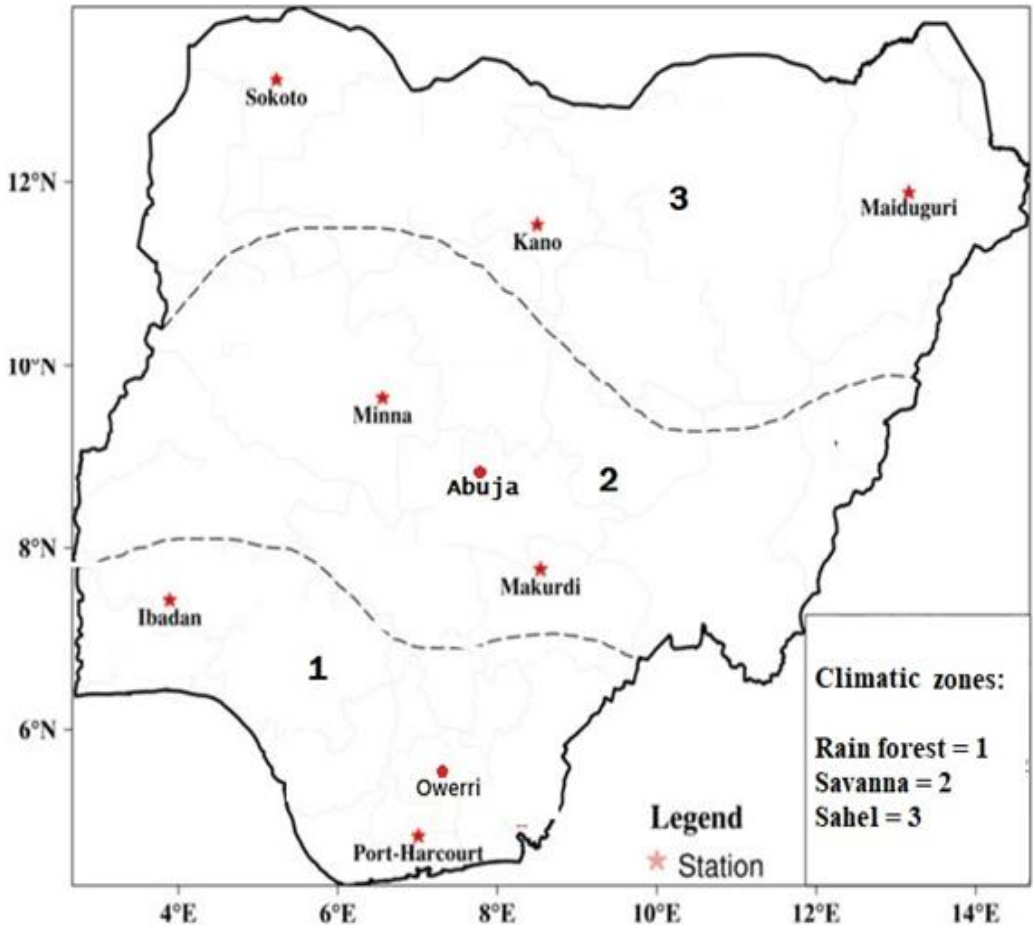


Figure 1. Map of Nigeria showing the study locations and the climatic zones.

## 2.2 Data acquisition

Observational data of monthly rainfall was obtained for a period of 42 years (1979 to 2021) from Nigerian Meteorological Agency (NiMET). The yearly productiondata for selected livestockwere obtained for a period of 10 years (2013 to 2022)from the Nigeria Federal Ministry of Agriculture and Natural Resources. The selected livestock are poultry, cattle, goat, sheep, pigs, dogs, cats and horses due to their importance to the local population for food and income. The nine study locations are Ibadan, Owerri and Portharcourt in the rain forest, Minna, Abuja and Makurdi in the Savanna, and Sokoto, Kano and Maiduguri in the Sahel, respectively. These locations were chosen because they are spread across each climatic zone. NiMET was chosen because they are responsible by law for observing, analyzing, and accurate reporting of weather and climate information. Figure shows map of Nigeria indicating the locations for NiMET data and their occurring climatic zones.

## 2.3 Data analysis

The data obtained were subjected to descriptive statistics. The mean, standard deviation and coefficient of variation shows spread and variability of the data. The linear regression indicates the trend (changes with time) during the climatology. The coefficient of correlation values revealed the statistical relationship between the compared variables (rainfall and each of the animal production data) whereas the t-test showed the significance (% confidence level) of the correlation.

## 3. Results and Discussion

### 3.1 Trend in livestock production in Nigeria

Figure 2 shows the Nigeria livestock production from 2013 to 2022. The production of poultry birds was highest for the years studied (2013 – 2022), followed by cattle, goat, sheep, dogs, pigs, cats and horses respectively. It is quite evident that the production of poultry is on the increase over the years in comparison to other livestock.Table 1 shows further details to the livestock production across Nigeria from 2013 to 2022. The livestock production shows varying degrees of variations. The poultry and cattle production data show positive trends. The rest of the livestock indicate negative trends over the period. Dogs and cats showed decline in production over the years, with cats showing higher variability than dogs. Horse production has remained relatively stable with a minor decrease over the years.

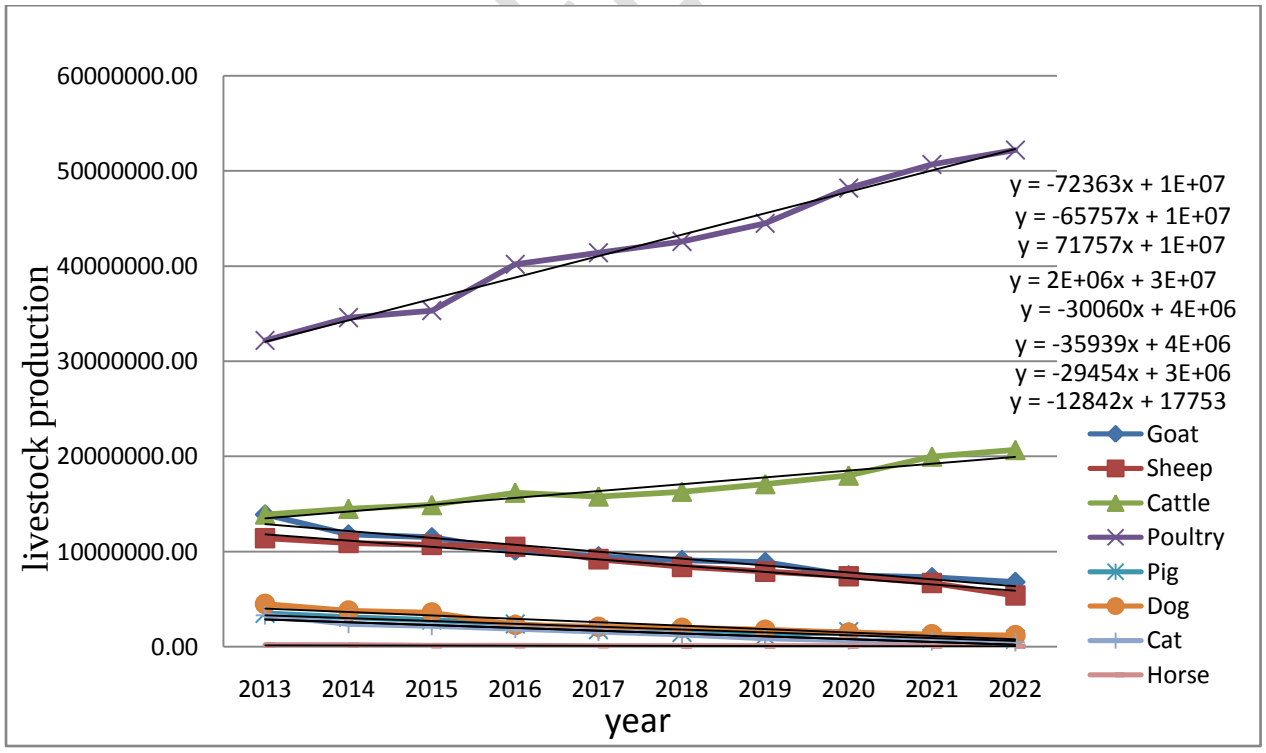


Figure 2. Nigeria livestock production from 2013 to 2022. The trend equations are inserted.

Table 1. Trend and variability of livestock production in Nigeria (2013 – 2022)

| Livestock | Mean | Standard Deviation | CV (%) | Trend($yr^{-1}$) |
|---|---|---|---|---|
| Goat | 9883333.33 | 2230020.97 | 22.56 | -723636 |
| Sheep | 8100000 | 1961859.45 | 24.24 | -657576 |
| Cattle | 17366666.67 | 2902679.94 | 16.72 | 717576 |
| Poultry | 40153333.33 | 8672300.91 | 21.59 | 2E+06 |
| Pigs | 1926666.67 | 749591.42 | 38.92 | -300606 |
| Dogs | 2646666.67 | 1016247.98 | 38.38 | -359394 |
| Cats | 1846666.67 | 930569.79 | 50.38 | -294545 |
| Horse | 113333.33 | 49686.55 | 43.81 | -12842 |

### 3.2 Trend and variability of Nigeria rainfall

Figure 3 show the annual rainfall averaged across the climatic zones (Guinea, Savanna and Sahel) from 1979 to 2021.The Guinea region received more rainfall with an average of 2060.853 mm/yr while the Sahel region received the least rainfall with an average of 642.6093 mm/yr (Table 2). The relatively low coefficient of variation (7.80%) at the Guinea region indicates moderate variability in rainfall. Its negative trend (-0.36 mm/yr) indicates a decreasing annual rainfall over the years, which could impact the water availability and ecosystem in the region. The Savanna region had an average annual rainfall of about 989.803 mm/yr. With a coefficient of variation of 8.39%, it indicated moderate variability in rainfall compared to the Guinea and Sahel regions. The positive trend (2.48 mm/yr) at the Savanna indicates an increasing annual rainfall, which hasattendant implications to the local population agricultural and environmental activities. The Sahel region experienced the lowest average annual rainfall of 642.225 mm/yr. The coefficient of variation (20.94%) suggests the highest variability in annual rainfall occurs over the Sahel. However, the positive trend (4.33mm/yr) implies the recovery of the droughts of the late 1970's and early 1980's across the Sahel, which have implications for water resources and agricultural activities in this semi-arid region.

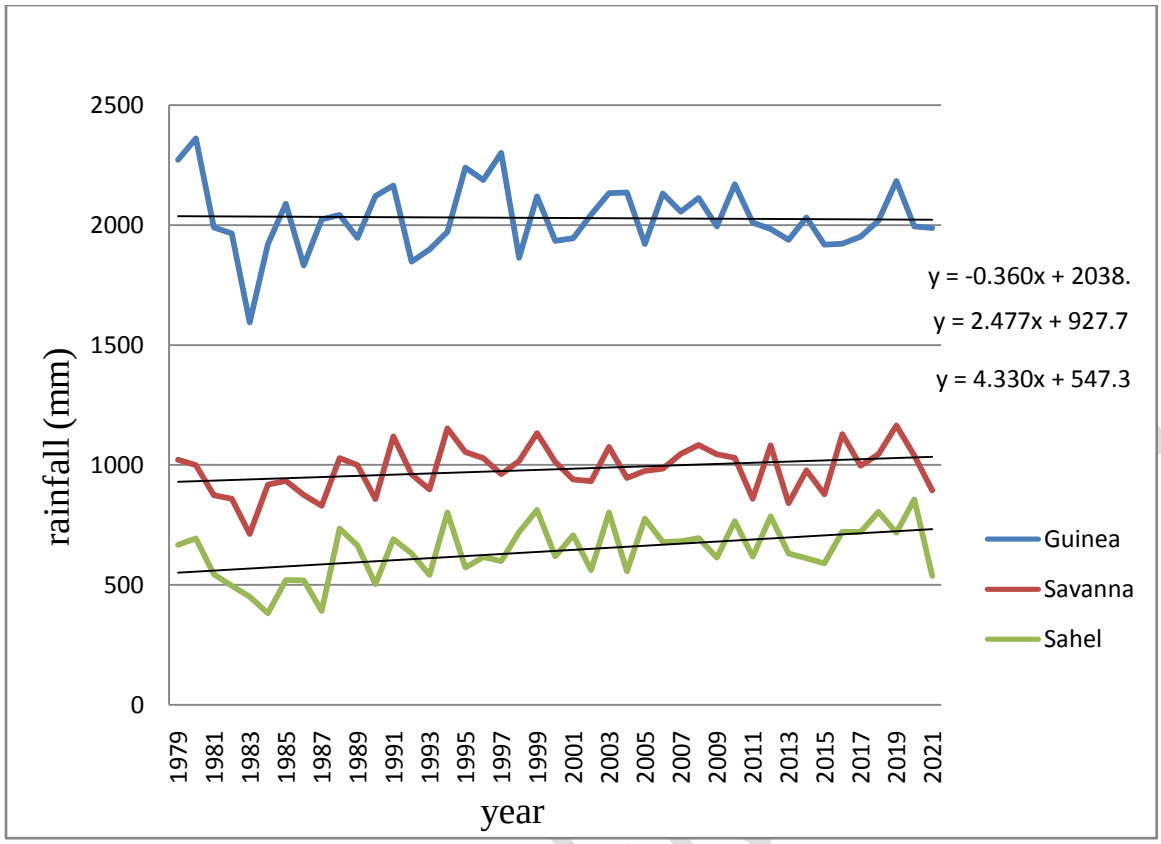


Figure 3. The annual rainfall averaged across the climatic zones (1979 to 2021) with the trends indicated.

Table 2. Statistical analysis of Nigeria annual rainfall at the climatic zones.

| Region | Mean (mm) | Standard Deviation(mm/yr) | CV (%) | Trend (mm/yr) |
|---|---|---|---|---|
| Guinea | 2060.853 | 160.686 | 7.80 | -0.36 |
| Savanna | 989.803 | 83.010 | 8.39 | 2.48 |
| Sahel | 642.225 | 134.525 | 20.94 | 4.33 |

### 3.3 Impact of rainfall variability on livestock production in Nigeria

Table 3 show the linear relationship between the livestock and annual rainfall at the climatic zones using the coefficient of correlation values. The negative correlation values indicate that rainfall trend causes reduction in production whereas positive values indicate the trend causes increment in the livestock production. The significant level of the correlation values at 95% confidence levels is indicated. In the Guinea region, there is a positive correlation between rainfall and goat production (0.487), while sheep production also shows a positive correlation in both the Guinea (0.325) and Savanna (0.277) regions. In the Sahel region, both goat and sheep

production exhibit a negative correlation with rainfall (-0.566 and -0.591 respectively), suggesting that increased rainfall might decrease their production.In the Savanna region, there is a positive correlation between rainfall and cattle production (0.233). However, the correlation is not significant.Poultry production shows a positive correlation with rainfall in both the Guinea (0.350) and Savanna (0.027) regions. The correlation is more significant in the Guinea region.For pigs, dogs, cats, and horse, they show weak correlations with rainfall across different regions.Overall, the correlations suggest that for certain livestock categories, rainfall changes can impact production, either positively or negatively. However, the significance of these correlations is mixed, and additional factors beyond rainfall may also influence livestock production. The significant correlations can provide some insight into potential impacts, but the non-significant correlations indicate that other factors might be equally or more important in explaining livestock production variability.

Table 3. Coefficient of correlation between the livestock and annual rainfall at the climatic zones.

| Livestock | Guinea | Savanna | Sahel |
|---|---|---|---|
| Goat | 0.487 | 0.072 | -0.566* |
| Sheep | 0.325 | -0.079 | -0.591* |
| Cattle | 0.108 | 0.233 | -0.454 |
| Poultry | 0.350 | 0.027 | 0.274 |
| Pigs | 0.150 | 0.277 | -0.048 |
| Dogs | 0.146 | 0.252 | -0.221 |
| Cats | 0.140 | 0.198 | -0.261 |
| Horse | 0.158 | 0.296 | -0.353 |

* indicates a significant correlation at 95% Confidence level from t-test.

## 4. Conclusion

This research work aimed at investigating climate variability and its impact on livestock production across Nigeria. The critical context of the study was established, highlighting the global growth of livestock sector and its environmental challenges. The nexus between livestock production and climate change was explored, emphasizing the significance of climate variability on animal production. The research problem of climate change's impact on livestock production was articulated, with a focus on Nigeria's rain-fed agriculture. The significance of the study was addressing the gaps in livestock research and understanding the evolving relationship between climate and livestock production was underscored.

Furthermore, the research provided a comprehensive literature review on the relationship between climate variability, livestock production, and environmental sustainability. The global rise in meat and milk production, coupled with the sector's environmental footprint, was discussed. The direct and indirect impacts of climate on livestock were examined, including the effects on animal performance, feed quality, and disease distribution. The study, considered distinct climatic regions of Nigeria and the significance of agriculture in its economy. Data acquisition sources were outlined, with observations spanning several decades from the Nigerian Meteorological Agency (NiMET) and Federal Ministry of Agriculture and Natural Resources. The methods of data analysis, including descriptive statistics, linear regression, coefficient of correlation, and student t test, were explained. These analyses were employed to uncover trends, relationships, and the significance of correlations in the collected data.

The analysis of climate variability and its impact on livestock production in Nigeria was extensively explored. The trends and variability of rainfall across different regions of Nigeria were analyzed over a span of decades, revealing insights into changing precipitation patterns. Positive and negative correlations were identified, indicating how changes in rainfall influenced livestock output. And the significance of these correlations was determined through t-tests, shedding light on the strength of the relationship between rainfall and livestock production.

The study provided crucial insights into the dynamic nature of climate patterns in the country. Following the complex interplay between climate and agricultural outcomes, specifically in the context of livestock, the understanding from this study enhances the capacity for informed decision-making in agriculture and resource management. This study's comprehensive analysis and findings enrich the understanding of climate-livestock dynamics in Nigeria, offering valuable insights for policymakers, researchers, and practitioners working towards sustainable agricultural development and climate resilience strategies.

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