VOL. 13 NO. 1,
AUGUST, 2026
E-ISSN 3027-0995
P-ISSN 3026-8265

African Scholar Publications & Research International
www.africanscholarpub.com

Journal of Biotechnology and Agricultural Research (JBAR)

Climatic Influences on Aggregate Livestock Production in Nigeria: A Time-Series Analysis of Satellite-Derived Reanalysis Data (2010-2024)

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DOI: https://doi.org/10.70382/ajbar.v13i1.046

Abstract

Climate change can significantly affect livestock production through its influence on environmental factors that determine animal health, productivity, and resource availability. Although livestock contributes substantially to Nigeria's agricultural economy and food security, there is limited empirical evidence quantifying the effects of specific climate risk indicators on livestock production. This study investigated the relationship between climate risk indicators and livestock production in Nigeria over a 15-year period (2010-2024) using annual data. Climate data, including temperature, rainfall, relative humidity, wind speed, and solar radiation, were obtained from NASA's Prediction of Worldwide Energy Resources (POWER) database, while livestock production data were sourced from the Food and Agriculture Organization of the United Nations (FAOSTAT). Data were analysed using descriptive statistics, Pearson Product-Moment Correlation, and multiple linear regression. The descriptive analysis revealed moderate variability in climatic parameters during the study period, with greater variability observed in livestock production. Pearson correlation analysis showed that livestock production had significant positive relationships with temperature ($r = 0.678$, $p < 0.01$) and solar radiation ($r = 0.542$, $p < 0.05$), while significant negative relationships were found with relative humidity ($r = -0.660$, $p < 0.01$) and wind speed ($r = -0.560$, $p < 0.05$). Rainfall exhibited a negative but non-significant relationship with livestock production ($r = -0.118$, $p > 0.05$). The overall multiple regression model was statistically significant ($F(5, 9) = 5.193$, $p = 0.016$) and explained 74.3% of the variation in livestock production ($R^2 = 0.743$, Adjusted $R^2 = 0.600$). However, none of the climate variables made a statistically significant unique contribution after controlling for the effects of the other variables. The findings highlight the collective influence of climate risk indicators on livestock production in Nigeria and underscore the need for integrated climate adaptation strategies within the livestock sector. The study also demonstrates the value of satellite-derived climate data for agricultural research in data-scarce environments. It provides empirical evidence to support climate-smart livestock management and policy development.

Keywords: Climate Change, Climate Risk Indicators, Livestock Production, Satellite Meteorological Data, FAOSTAT, NASA POWER, Nigeria.

Introduction

Climate change is one of the most critical challenges facing global agriculture, significantly affecting both crop production and animal husbandry. The combined effects of rising global temperatures, changing precipitation patterns, increasing frequency of extreme weather events, and higher atmospheric concentrations of carbon dioxide make agricultural systems more vulnerable and reduce their productivity (Godde et al., 2021). In developing regions, these changes increase vulnerability to pests and diseases, soil degradation, and water scarcity, further compounded by dependence on rain-fed agricultural systems and limited adaptive capacity. Consequently, agricultural productivity and long-term sustainability are expected to decline under various climate change scenarios (Sejian, 2016). Within this context, livestock production is among the most vulnerable agricultural sectors because heat stress, changes in forage availability, and water resource constraints directly affect animal health and productivity.

In Sub-Saharan Africa, livestock plays a vital and multifaceted role in agricultural economies. Beyond providing protein through meat, milk, and eggs, livestock serves as a source of income, employment, draught power, manure for soil fertility, and cultural value in many rural communities (Food and Agriculture Organization of the United Nations, n.d.; Omokaro, 2025). In Nigeria, the livestock sector supports millions of smallholder farmers and pastoralists and serves as a buffer against economic shocks and poverty. The cattle industry, in particular, is one of the most important agricultural subsectors, contributing significantly to meat production, trade, and nutritional security. In addition, livestock contributes to the resilience of mixed farming systems through income diversification. However, it remains highly vulnerable to climatic changes that affect animal physiology, feed resources, and overall productivity (Godde et al., 2021).

Nigeria experiences considerable climatic variability characterised by rising temperatures, irregular rainfall patterns, prolonged dry spells, and an increasing frequency of extreme weather events such as floods and droughts. These trends are consistent with observations across West Africa, where evidence indicates increasing mean annual temperatures and changing seasonal rainfall patterns over recent decades (Omokaro, 2025). In the northern and central regions, where much of the country's livestock production is concentrated, aridity and heat waves contribute to water scarcity and declining pasture quality. In contrast, the southern regions frequently experience excessive humidity and flooding. These climatic challenges are further compounded by land degradation, resource conflicts, and other socio-economic pressures. Satellite-derived climate data and long-term meteorological records increasingly highlight the need for a better understanding of these interactions to support targeted adaptation strategies (NASA Langley Research Center, n.d.; Carrara et al., 2023).

Statement of the Problem

Climate change has become one of the most significant challenges confronting livestock production in Nigeria. Rising temperatures, irregular rainfall patterns, and other climatic extremes are increasingly affecting the productivity, sustainability, and resilience of the

livestock sector. Climatic changes influence forage quality and quantity, water availability, heat stress levels, and susceptibility to disease outbreaks, all of which contribute to reduced productivity and economic losses. These challenges are particularly concerning in Nigeria, where livestock production remains a critical source of food, income, employment, and rural livelihoods. Consequently, understanding the effects of climate variability on livestock production has become increasingly important for achieving food security and sustainable agricultural development.

Although the impacts of climate change on agriculture have been widely documented, much of the existing literature has focused on crop production, farmers' perceptions of climate change, or broader environmental impacts. Comparatively fewer studies have examined the effects of climate variability on livestock production. Furthermore, many previous studies have relied on survey data or conventional meteorological records, which may not adequately capture the spatial and temporal variability of climatic conditions. Recent advances in remote sensing have made satellite-derived climate data increasingly available, providing consistent and objective measures of climate risk indicators such as temperature, rainfall, relative humidity, wind speed, and solar radiation. Despite these advancements, empirical studies that integrate these climate indicators to examine their influence on livestock production in Nigeria remain limited.

The scarcity of empirical evidence on the effects of specific climate risk indicators on livestock production constrains the development of effective climate adaptation and mitigation strategies for the livestock sector. Without comprehensive evidence, policymakers, agricultural planners, and livestock producers have limited information for identifying the climatic factors that most strongly influence livestock productivity and system resilience. This knowledge gap hinders the design and implementation of targeted interventions aimed at improving the sustainability of livestock production under changing climatic conditions. Therefore, this study seeks to address this gap by examining the relationship between selected climate risk indicators and livestock production in Nigeria using satellite-derived climate data and official livestock production statistics. The findings are expected to provide empirical evidence that will support climate-smart livestock management, inform policy development, and contribute to the long-term sustainability of livestock production systems in Nigeria.

Purpose of the Study

This study aims to examine the relationship between climate risk indicators and livestock production in Nigeria using satellite-derived environmental data. Specifically, the study seeks to:

1. determine the characteristics of selected climate risk indicators and livestock production in Nigeria;
2. examine the relationships between climate risk indicators (temperature, precipitation, relative humidity, wind speed, and solar radiation) and livestock production in Nigeria; and
3. determine the extent to which climate risk indicators predict livestock production in Nigeria.

Research Questions

The study is guided by the following research questions:

1. What are the characteristics of selected climate risk indicators and livestock production in Nigeria?
2. What relationships exist between climate risk indicators and livestock production in Nigeria?
3. To what extent do climate risk indicators predict livestock production in Nigeria?

Significance of the Study

The findings of this study will contribute to both theory and practice by expanding existing knowledge on the effects of climate variability on livestock production in Nigeria. By utilising satellite-derived reanalysis and meteorological data, the study provides an objective and data-driven assessment of climate risk indicators, complementing previous studies that have relied primarily on survey data or conventional meteorological records. The integration of satellite-derived reanalysis and meteorological data with official livestock production statistics further demonstrates the value of geospatial climate data in agricultural and livestock research.

The study will provide empirical evidence that can assist policymakers in developing climate-sensitive strategies to enhance the resilience and sustainability of Nigeria's livestock sector. The findings may inform the design and implementation of targeted adaptation measures, including climate-smart livestock management practices, improved early warning and forecasting systems, and more efficient resource allocation.

The study will also benefit livestock producers and agricultural extension practitioners by improving understanding of the effects of climate variability on livestock production. The findings can support informed decision-making regarding grazing management, water resource utilisation, and adaptation strategies aimed at reducing climate-related risks.

From a scholarly perspective, the study contributes to the growing body of literature on climate risk, remote sensing, and agricultural sustainability in developing countries. It also provides a methodological framework for integrating satellite-derived climate data with agricultural production statistics and serves as a foundation for future research employing advanced geospatial and predictive analytical techniques to investigate climate-related challenges in the livestock sector.

Literature Review

Climate Risk Indicators and Livestock Production

Climate risk indicators are important environmental factors that influence livestock production by affecting animal physiology, forage production, water availability, and the overall efficiency of livestock systems. The effects of climate variability on livestock productivity involve complex biological and ecological processes that vary across agroecological zones. Key climate risk indicators that significantly influence livestock production include temperature, precipitation, relative humidity, wind speed, and solar radiation, each of which affects livestock health, growth, and productivity in different ways.

Temperature is widely recognised as one of the most important climatic factors affecting livestock production. High temperatures expose animals to heat stress, which reduces feed intake, alters metabolic processes, increases respiration rates, and impairs reproductive performance. These physiological responses ultimately lead to reduced weight gain and lower meat production, particularly in tropical production systems where animals are exposed to prolonged periods of heat. Studies conducted in tropical regions have shown that increasing temperatures negatively affect livestock productivity, while research in Nigeria and other West African countries has linked rising mean annual temperatures to increased livestock mortality during peak dry seasons (Thornton et al., 2022; Sejian et al., 2018). These findings suggest that livestock production is highly vulnerable to global warming.

Rainfall is another important climate risk indicator because it directly influences pasture productivity and water availability for livestock. Adequate and well-distributed rainfall promotes forage growth and favourable grazing conditions, whereas insufficient or erratic rainfall contributes to drought and pasture degradation. Previous studies have shown that changes in rainfall patterns negatively affect cattle body

condition, milk production, and overall herd productivity. Across many regions of Sub-Saharan Africa, prolonged dry spells have been associated with reduced herd sizes, lower slaughter weights, and increased vulnerability of livestock systems to climatic shocks (Godde et al., 2021). Consequently, rainfall variability remains a major risk factor for livestock production.

Relative humidity also plays a significant role in livestock production because of its interaction with ambient temperature. Under conditions of high humidity, evaporative cooling becomes less effective, thereby increasing heat stress and physiological strain on animals. This can lead to reduced feed intake, slower growth rates, and increased susceptibility to diseases, even at moderately high temperatures. Empirical studies have reported that the combined effects of high temperature and high humidity significantly reduce livestock productivity in humid tropical environments and contribute to various animal health challenges (Ogunlowo et al., 2024; Adjassin et al., 2020).

Although less frequently studied, wind speed is another important factor influencing livestock well-being because it affects the exchange of heat between animals and their environment. Moderate wind speeds enhance heat dissipation and improve thermal comfort, thereby reducing the adverse effects of high temperatures. In contrast, low wind speeds restrict cooling and increase thermal discomfort, while excessively high wind speeds may result in physiological stress and increased energy expenditure. Evidence from African pastoral production systems suggests that favourable wind conditions support livestock productivity, whereas extreme wind conditions may reduce animal performance.

Solar radiation is another important climatic factor affecting livestock production. Measured as surface shortwave irradiance, solar radiation reflects the intensity of incoming solar energy reaching the Earth's surface. High levels of solar radiation increase radiant heat load, elevate body temperature, and increase the energy required for thermoregulation. In extensive grazing systems, prolonged exposure to intense solar radiation may reduce grazing efficiency, feed intake, and overall animal performance. Studies using satellite-derived climate data have reported strong relationships between high solar radiation levels and reduced livestock productivity in open grazing environments (Yusuf et al., 2022; Bonachea et al., 2022).

These climate risk indicators do not operate independently. Rather, they interact in complex ways to influence livestock physiology, pasture conditions, water availability, and disease dynamics, ultimately affecting livestock productivity. Understanding both their individual and combined effects is therefore essential for developing effective adaptation strategies. Consequently, this study examines the relationships between selected climate risk indicators and livestock production in Nigeria using satellite-derived climate data and official livestock production statistics.

Remote Sensing in Climate and Agricultural Research

Remote sensing technology has emerged as an indispensable tool for monitoring climatic conditions and supporting agricultural research due to its ability to provide consistent spatial and temporal observations of the environment over large areas at relatively low cost. Compared with conventional ground-based meteorological stations, satellite-based observations offer extensive spatial coverage and continuous monitoring, making them particularly valuable in developing countries where meteorological infrastructure is often limited. Consequently, remote sensing has significantly enhanced researchers' ability to assess climate variability and its potential impacts on agricultural systems (NASA Langley Research Center, n.d.; Carrara et al., 2023).

One of the most widely used satellite-based climate information systems is the National Aeronautics and Space Administration's Prediction of Worldwide Energy Resources (NASA POWER) database. This platform integrates data from multiple satellite sources to provide high-quality climate variables,

including air temperature, precipitation, relative humidity, wind speed, and solar radiation at various temporal scales. NASA POWER has become an increasingly important source of climate data for agro-climatological and environmental research, particularly in tropical regions, because of its accessibility, consistency, and strong agreement with surface meteorological observations (NASA Langley Research Center, n.d.; Carrara et al., 2023).

Satellite-derived climate data offer numerous advantages for agricultural research. They facilitate continuous monitoring of climatic conditions, support assessments of climate variability, and enable researchers to evaluate climate-related risks that affect agricultural production. In regions with limited meteorological infrastructure, these datasets serve as reliable alternatives for studying climatic phenomena and improving agricultural planning. Furthermore, the integration of satellite-derived reanalysis and meteorological data with agricultural production data has enhanced the development of predictive models, drought-monitoring systems, and climate adaptation strategies aimed at improving food security (Yusuf et al., 2022).

The application of remote sensing in livestock research has expanded considerably in recent years. Satellite-derived climate data have been used to develop heat stress indices, monitor pasture conditions, assess grazing resources, and investigate the effects of temperature and solar radiation on livestock productivity. Previous studies have utilised NASA POWER data to examine thermal stress in cattle and small ruminants, reporting strong relationships between satellite-derived climatic variables and animal physiological responses, productivity, and welfare. These datasets are particularly useful for large-scale grazing systems where conventional weather stations are scarce or limited to specific locations (Adjassin et al., 2020; Thornton et al., 2022).

The growing application of remote sensing technologies in agricultural research has significantly improved the capacity to address climate-related challenges affecting agricultural production. This study contributes to this growing body of research by examining the relationship between climate variability and livestock production in Nigeria using satellite-derived climate indicators from NASA POWER. The findings are expected to demonstrate the usefulness of satellite-derived reanalysis and meteorological data in supporting climate-resilient livestock management practices and evidence-based agricultural policy development.

Theoretical Framework

Livestock Production Function Framework is the theoretical framework used to explore the effects of environmental conditions on livestock production. The framework aims at conceptualizing the process of livestock production as a result of the interaction among production inputs and environment in which the animals are kept. Climatic conditions may impact livestock productivity in livestock systems through impact on animal physiology, feed availability, water supplies and thermal comfort. Studies in Nigeria show that changes in temperature, rainfall and other climatic factors can impact livestock by causing heat stress, water shortages, feed shortages and an increased risk of disease (Ojo et al., 2024).

In this context, climatic factors like temperature, rainfall, relative humidity, wind speed and solar radiation are considered as determinants of livestock production. Thermal environment experienced by animals is affected by temperature and humidity, and heat dissipation is affected by wind speed. Radiant heat exposure includes solar radiation especially in outdoor production systems. The impact of rainfall on the availability of pasture and water has a direct impact on resources needed for livestock production. The empirical evidence obtained from Nigeria also shows that the climatic variables can have measurable relationships with the livestock production outcomes (Gershon & Mbajekwe, 2020).

The framework is relevant for this study as it reflects the national data and variables used in this study for annual data. It offers a foundation to explore the individual and joint impacts of climate risk indicators on livestock production, while avoiding the need to make assumptions about unobserved adaptations at the farmer level or land-value decisions. The study then uses the framework to determine if there is any relationship between the differences in the climatic indicators and differences in livestock production in Nigeria.

Methodology

This study adopted a quantitative research approach using an ex post facto research design to examine the influence of climate risk indicators on livestock production in Nigeria. Data were obtained from two internationally recognised databases covering the period from 2010 to 2024.

The dependent variable was livestock production, measured as the total annual production of major livestock commodities, including cattle, goats, sheep, pigs, and chickens. Livestock production data were obtained from the Food and Agriculture Organization of the United Nations Statistical Database (FAOSTAT), a globally recognised repository of official agricultural statistics.

The independent variables comprised five climate risk indicators: mean annual temperature (°C), rainfall (mm/day), relative humidity (%), wind speed (m/s), and all-sky surface shortwave downward irradiance (MJ/m²/day), which served as a measure of solar radiation. Data for these variables were obtained from the National Aeronautics and Space Administration's Prediction of Worldwide Energy Resources (NASA POWER) database, a validated remote sensing platform that provides satellite-derived meteorological data for agricultural and environmental research.

The study adopted a national-level analytical approach to ensure temporal and spatial consistency between the climate and livestock production datasets. The analysis utilised annual climate indicators representing Nigeria as a whole and corresponding national livestock production statistic for the period 2010-2024. National aggregation was considered appropriate because the study sought to examine the overall relationship between climate risk indicators and livestock production at the national scale rather than estimate effects for specific ecological zones or livestock species. Furthermore, consistent regional-level livestock production data that could be reliably matched with spatially corresponding climate observations across the entire study period were not available in a sufficiently standardised form for the analysis. Using national-level observations therefore provided a consistent unit of analysis across the two datasets and avoided combining spatially and temporally incompatible data. Nevertheless, the national approach may mask regional and species-specific differences in climate exposure and livestock responses. The findings should consequently be interpreted as national-level statistical associations and should not be generalised directly to individual ecological zones, locations, or livestock production systems.

The climate and livestock datasets were downloaded separately and merged using the year as the common identifier. The final dataset was imported into IBM SPSS Statistics Version 27 for analysis, while preliminary data cleaning and organisation were carried out using Microsoft Excel.

Data analysis was conducted in three stages. First, descriptive statistics, including the mean, standard deviation, minimum value, and maximum value, were computed to summarise the characteristics of the study variables. Second, Pearson Product-Moment Correlation analysis was used to determine the direction and strength of the relationships between the climate risk indicators and livestock production. Third, multiple linear regression analysis was performed to examine the combined and individual predictive effects of temperature, rainfall, relative humidity, wind speed, and solar radiation on livestock production.

Prior to conducting the regression analysis, the assumptions of multiple linear regression were tested. Normality of residuals was assessed using a histogram and a Normal P-P Plot of standardised residuals. Homoscedasticity was evaluated through a scatterplot of standardised residuals against standardised predicted values, while the Durbin-Watson statistic was used to assess the independence of errors. Multicollinearity among the predictor variables was examined using tolerance values and Variance Inflation Factors (VIFs). The diagnostic results indicated that all assumptions were adequately satisfied, confirming the suitability of the regression model for the analysis.

All statistical analyses were conducted at a 0.05 level of significance. The analytical procedures enabled the study to determine the nature and strength of the relationships between selected climate risk indicators and livestock production, as well as the proportion of variance in livestock production explained by the climate variables individually and collectively in Nigeria.

Results

Descriptive Statistics

The descriptive statistics of the climate risk indicators and livestock production for the period of 2010 to 2024 for Nigeria is summarized in Table 1. The results obtained showed that the mean annual temperature during the study period was 26.51°C (SD = 0.29), ranging from 26.10°C to 27.04°C; while rainfall showed a mean value of 4.47 (SD = 0.69), ranging from 3.12 to 5.79. Relative humidity exhibited a mean of 85.67% (SD = 0.70), while wind speed averaged 2.22 m/s (SD = 0.05). The solar radiation obtained the average of 16.53 MJ/m^2/day (SD = 0.24). Livestock production averaged 1,315,760.96 tonnes (SD = 130,309.65), ranging from 1,106,010.11 to 1,501,135.86 tonnes.

Table 1

Descriptive Statistics of Climate Risk Indicators and Livestock Production (2010-2024)

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Temperature (°C)	15	26.10	27.04	26.506	0.286
Rainfall	15	3.12	5.79	4.472	0.694
Humidity (%)	15	84.49	86.72	85.665	0.698
Wind Speed (m/s)	15	2.15	2.33	2.222	0.053
Solar Radiation (MJ/m²/day)	15	16.14	16.91	16.532	0.242
Livestock Production (tonnes)	15	1,106,010.11	1,501,135.86	1,315,760.96	130,309.65

Relationship Between Climate Risk Indicators and Livestock Production

The relationship between the climate risk indicators and livestock production was carried out by Pearson product-moment correlation analysis for Nigeria. As shown in Table 2, the livestock production was found to be significantly and highly positively related to temperature (r = .678, p = .005), which meant that years with relatively high temperatures had high livestock production. Livestock production also showed a good positive correlation with solar radiation (r = 0.542, p = 0.037).

The relationship between relative humidity and livestock production was, on the other hand, very negative and statistically significant (r = -0.660, p = 0.007), where livestock production was negatively correlated with an increase in humidity. Livestock production was also negatively correlated with wind speed (r = -0.560, p = 0.030). But there was a weak negative correlation between rainfall and livestock production (r = -0.118), which was not statistically significant (p = 0.674).

The correlation matrix also showed that some of the independent variables were moderately correlated. There was a negative correlation between temperature and wind speed (r = -0.650, p = 0.009) and a

positive correlation between rainfall and humidity (r = 0.573, p = 0.026), with negative correlation between humidity and solar radiation (r = -0.573, p = 0.026). None of these correlation coefficients were greater than the typical limit for severe multicollinearity.

Table 2

Pearson Correlation Matrix for Climate Risk Indicators and Livestock Production

Variable	1	2	3	4	5	6
Temperature	1					
Rainfall	.160	1				
Humidity	-.438	.573*	1			
Wind Speed	-.650**	-.341	.132	1		
Solar Radiation	.310	-.386	-.573*	.015	1	
Livestock Production	.678**	-.118	-.660**	-.560*	.542*	1

Predictive Influence of Climate Risk Indicators on Livestock Production

The assumptions of the multiple regression were first tested before estimating the regression model. The standardized residuals were plotted against the histogram, which suggested that the residuals were normally distributed, and the Normal P-P Plot revealed that the cumulative probabilities were close to the diagonal line, with some deviations from normality. In addition, the scatter plot of standardized residuals versus standardized predicted values showed a random distribution of points around the zero line with no obvious pattern, which reasonably satisfied the assumption of homoscedasticity.

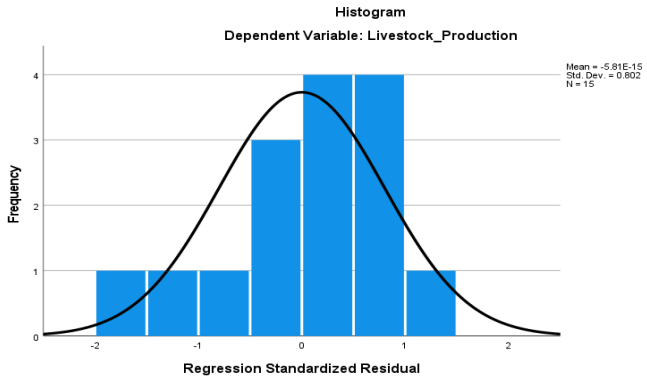


Figure 1

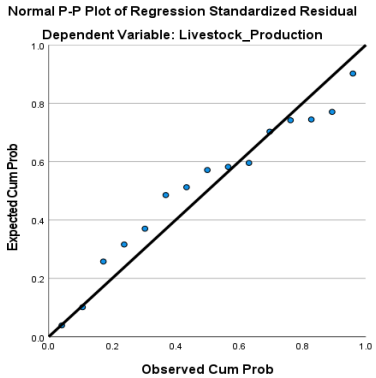


Figure 2

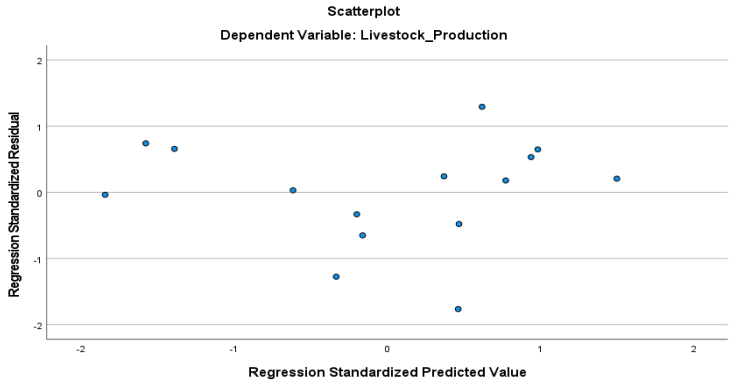


Figure 3

In addition, the multicollinearity diagnostics revealed that the predictor variables presented no serious problems of multicollinearity. Tolerance values were between 0.351 and 0.627 and Variance Inflation Factor (VIF) values were between 1.594 and 2.849, which are within the acceptable range. The Durbin-Watson statistic of 1.119 indicated there was some positive autocorrelation, which may be an expected result for annual time-series data with a relatively small number of observations.

The model was statistically significant and $F_{(5, 9)} = 5.193$, $p = 0.016$, explained the production of livestock in Nigeria by the climate risk indicators. The model obtained a multiple correlation coefficient of r = .862 and r = 0.743 which means that the combination of temperature, rainfall, humidity, wind speed and solar radiation explained about 74.3% of the variations in livestock production as indicated in Table 3. The adjusted coefficient of determination was 0.600, representing 60.0% of the variance in livestock production, after adjusting the coefficient to account for the number of predictors in the model and the sample size.

Table 3
Model Summary for Multiple Regression Analysis

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F	Durbin-Watson
1	.862[a]	.743	.600	82455.14016	.743	5.193	1.119

Table 4
Analysis of Variance (ANOVA)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	176538807643.44	5	35307761528.69	5.193	.016[b]
	Residual	61189651249.93	9	6798850138.88		
	Total	237728458893.37	14			

Despite the statistical significance of the overall regression model, none of the individual climate risk indicators made a statistically significant unique contribution to livestock production after controlling for the effects of the remaining variables. Temperature exerted a positive but non-significant effect (β = .124, $t = 0.450$, $p = .663$), while rainfall also showed a positive but non-significant influence (β = .091, $t = 0.354$, $p = .732$). Relative humidity exhibited a negative relationship with livestock production

(β = -.437, t = -1.532, p = .160), although the effect was not statistically significant. Similarly, wind speed demonstrated a negative but non-significant contribution (β = -.395, t = -1.654, p = .132), whereas solar radiation had a positive but non-significant effect (β = .295, t = 1.380, p = .201).

Table 5
Multiple Regression Coefficients for Climate Risk Indicators Predicting Livestock Production

Predictor	B	β	t	Sig.	Tolerance	VIF
Constant	6,255,432.328	-	0.848	0.418	-	-
Temperature	56,459.286	0.124	0.450	0.663	0.378	2.644
Rainfall	17,084.107	0.091	0.354	0.732	0.433	2.309
Humidity	-81,659.182	-0.437	-1.532	0.160	0.351	2.849
Wind Speed	-963,178.240	-0.395	-1.654	0.132	0.501	1.996
Solar Radiation	158,659.675	0.295	1.380	0.201	0.627	1.594

Overall, the results suggest that all the individual climate indicators as well as the combination of these variables as indicators created a model that explained a significant portion of the variation in livestock production, but none of the climate variables alone had a statistically significant effect after controlling for the effects of the other variables. This implies that the overall interaction between climatic conditions, and not any one climatic risk indicator is likely to influence livestock production in Nigeria more.

Discussion

This study examined the relationship between climate risk indicators and livestock production in Nigeria using satellite-derived climate data obtained from the NASA POWER database and livestock production statistics from the Food and Agriculture Organization (FAO). The findings indicated that the selected climate risk indicators were collectively associated with variation in livestock production, although the strength and statistical significance of the individual climatic factors varied.

The descriptive statistics indicated that climatic conditions remained relatively stable during the study period, with moderate variations in temperature, rainfall, relative humidity, wind speed, and solar radiation. In contrast, livestock production exhibited greater variability. This variation may be attributed not only to climatic conditions but also to other production-related factors such as disease outbreaks, feed availability, market conditions, government policies, and livestock management practices. This observation supports the view that livestock production is a complex system influenced by multiple interacting factors, of which climate represents only one component (Godde et al., 2021).

The correlation analysis revealed significant positive relationships between livestock production and both temperature and solar radiation, while significant negative relationships were observed between livestock production and relative humidity and wind speed. However, rainfall did not demonstrate a statistically significant relationship with livestock production. The positive association between temperature and livestock production contrasts with previous studies that reported adverse effects of high temperatures on livestock productivity (Sejian et al., 2018). This finding does not necessarily suggest that higher temperatures are beneficial to livestock production. Rather, it may indicate that the temperature range experienced during the study period did not exceed critical thresholds capable of causing substantial production losses. The observed association may also reflect concurrent changes in livestock management, veterinary services, breed composition, feeding strategies, or other production

conditions during the study period, although these factors were not directly measured in the present analysis.

Similarly, the positive relationship between solar radiation and livestock production should also be interpreted cautiously. Solar radiation can contribute to the environmental conditions that support vegetation productivity, while excessive radiant exposure may increase heat load and physiological stress in livestock. Previous research has demonstrated that solar radiation is relevant to animal thermal conditions and feed-related outcomes (Bonachea et al., 2022; Yusuf et al., 2022). However, the present study did not directly measure pasture productivity, forage availability, animal heat stress, or feed intake. Therefore, the observed positive association cannot be attributed specifically to increased photosynthetic activity or improved pasture growth. The relationship may instead reflect the combined effects of climatic conditions and other production factors operating over the study period.

The negative relationships observed between relative humidity, wind speed, and livestock production are broadly consistent with existing literature. High humidity can reduce the efficiency of evaporative cooling, thereby increasing thermal discomfort and physiological stress in animals (Adjassin et al., 2020; Ogunlowo et al., 2024). Similarly, moderate wind speeds may facilitate heat dissipation, although the relationship between wind conditions and animal thermal comfort depends on the prevailing temperature, humidity and production environment. The negative association observed for wind speed in the present study should therefore not be interpreted as evidence that increased wind speed directly reduces livestock production. Rather, it indicates that the two variables moved in opposite directions during the study period, potentially reflecting their interaction with other environmental and production conditions.

Although rainfall is widely recognized as an important determinant of pasture growth and water availability, no significant relationship was found between rainfall and livestock production in this study. This finding suggests that annual rainfall totals may not adequately capture the seasonal distribution, intensity, and duration of rainfall events that directly influence grazing systems. Factors such as rainfall variability, drought frequency, and forage availability may be more closely related to livestock production than total annual rainfall. Future studies may therefore benefit from using seasonal or monthly precipitation indices to provide a more detailed assessment of rainfall impacts on livestock productivity.

The multiple regression analysis showed that the five climate risk indicators jointly accounted for 74.3% of the observed variance in aggregate livestock production, with the overall model reaching statistical significance, $F_{(5, 9)} = 5.193$, $p = 0.016$. However, none of the individual climate indicators made a statistically significant unique contribution when the other predictors were controlled. The significant overall model therefore should not be interpreted as evidence that any individual climatic variable independently caused changes in livestock production. Rather, the result indicates that the selected climatic indicators, considered jointly, were statistically associated with variation in livestock production during the study period. The relatively high proportion of explained variance may also reflect the influence of unmeasured factors that changed concurrently with the climate indicators, particularly because the analysis was based on annual observations and did not control for broader production, socioeconomic, technological or herd-related trends.

The regression diagnostics provided some support for the underlying assumptions, although they should be interpreted cautiously given the small number of annual observations. The VIF values ranged from 1.594 to 2.849, indicating no severe multicollinearity according to conventional VIF criteria. The histogram and Normal P-P plot suggested that the residuals were approximately normally distributed, while the residual scatterplot did not show an obvious systematic pattern or pronounced funnel shape.

However, the Durbin-Watson statistic of 1.119 indicates that potential serial dependence cannot be completely ruled out. Consequently, the regression estimates should be interpreted as exploratory rather than definitive.

Overall, the findings contribute to the growing body of evidence that climatic conditions are statistically associated with agricultural production through multiple interconnected environmental pathways, including livestock production. The study also highlights the usefulness of satellite-derived climate data in agricultural research and demonstrates how remotely sensed climate observations can be integrated with agricultural production statistics to generate empirical evidence for climate risk assessment and adaptation planning in Nigeria.

Conclusion

This study examined the statistical relationships between selected climate risk indicators and livestock production in Nigeria using annual climate data obtained from the NASA POWER database and livestock production data sourced from the Food and Agriculture Organization. The findings showed that livestock production was positively associated with temperature and solar radiation and negatively associated with relative humidity and wind speed, while rainfall did not demonstrate a statistically significant association with livestock production during the study period.

The multiple regression analysis indicated that the selected climate indicators jointly explained 74.3% of the observed variation in aggregate livestock production, and the overall model was statistically significant. However, none of the individual climate indicators made a statistically significant unique contribution when the other variables were controlled. The findings therefore suggest that the selected climate indicators were collectively associated with livestock production, but they do not provide sufficient evidence to attribute changes in livestock production to any individual climatic factor. The observed relationships may also reflect the influence of non-climatic factors and broader temporal changes in the Nigerian livestock sector.

The study further demonstrates the potential value of satellite-derived climate datasets for climate risk assessment in agricultural research, particularly where spatially and temporally consistent meteorological observations are limited. The findings can provide a basis for further investigation of climate-related livestock risks and inform adaptation planning. Future research should combine climate indicators with production, herd, health, feed, technological and socioeconomic variables to better distinguish climatic relationships from other determinants of livestock production in Nigeria.

Limitations of the Study

This study has several limitations that should be considered when interpreting the findings.

First, the analysis was based on 15 annual observations spanning 2010-2024. The small number of observations limits statistical power and reduces the stability and generalisability of the regression estimates. It also makes it difficult to distinguish relationships associated with climatic variation from underlying temporal trends. A longer time series, or analysis based on appropriately aggregated monthly or seasonal observations, could provide greater statistical power and more robust estimates of climate-livestock relationships.

Second, the study utilised national-level aggregate data, which may have masked important regional and species-specific variations across Nigeria's diverse ecological zones and livestock production systems. The use of national annual climate indicators and aggregate livestock production was intentional to maintain a consistent unit of analysis across the study period, particularly given the absence of sufficiently standardised regional livestock production data that could be reliably matched

with corresponding climate observations. However, national aggregation may conceal relationships that occur at regional or species-specific levels. Future research should therefore consider spatially disaggregated analyses where sufficiently consistent climate and livestock production data become available.

Third, the study did not incorporate several potentially important non-climatic determinants of livestock production, including feed availability, herd size and growth, disease prevalence, vaccination and other animal health interventions, veterinary services, market access, government policies, conflicts affecting grazing systems, management practices, technological adoption and broader socioeconomic conditions. The omission of these variables means that the observed relationships between climate indicators and livestock production may partly reflect concurrent changes in the wider livestock production system. Their exclusion also limits the ability of the model to distinguish climate-related associations from broader temporal and structural trends.

Finally, the study relied on satellite-derived climate data. Although NASA POWER data have been widely validated and extensively used in agricultural and environmental research, slight discrepancies may exist between satellite-derived estimates and ground-based meteorological observations.

A major limitation of the study is the exclusion of several non-climatic determinants of livestock production. Variables such as feed availability, herd size, vaccination and animal health interventions, technological adoption, management practices and socioeconomic conditions were not incorporated into the analysis. Their omission means that the estimated relationships between climate indicators and livestock production may partly capture broader temporal and structural changes in the livestock sector. In addition, the analysis was based on 15 annual observations, which limits statistical power and the ability to distinguish climatic relationships from underlying time trends. The findings should therefore be interpreted as exploratory associations rather than evidence of causal effects.

Recommendations

Based on the findings of this study, the following recommendations are proposed:

1. Government agencies should strengthen climate-smart livestock policies by integrating climate information into livestock planning, grazing management, and agricultural extension programmes.
2. Livestock producers should be encouraged to adopt climate adaptation measures such as the provision of shade structures, improved water access, climate-adapted housing systems, rotational grazing practices, and heat-stress management strategies.
3. Meteorological agencies and agricultural institutions should increase the use of satellite-derived climate information to improve climate monitoring, forecasting, and early warning systems for the livestock sector.
4. Policymakers should invest in climate-resilient livestock production systems through improved pasture management, cultivation of drought-resistant forage species, efficient water resource utilization, and enhanced veterinary services.
5. Future studies should utilize longer time-series datasets, higher temporal resolutions (monthly or seasonal observations), and spatially disaggregated regional datasets to provide a more comprehensive understanding of climate-livestock relationships in Nigeria.
6. Future research should incorporate economic, institutional, and farm-management variables to provide a broader understanding of the factors influencing livestock productivity under changing climatic conditions.

7. Advanced analytical approaches such as time-series econometric models, spatial econometric techniques, machine learning methods, and panel data analysis should be employed in future studies to improve predictive accuracy and deepen understanding of climate impacts on livestock production.

References

Adjassin, J. S., Alassane, A., & Houinato, M. (2020). Heat stress under different climate conditions for dairy cattle in Benin. *Livestock Research for Rural Development*. https://www.lrrd.org/lrrd32/5/alass32078.html

Bonachea, L., Serrano, J. O., et al. (2022). Effect of short-term radiation stress on physiological and hematological parameters in Pelibuey sheep in Cuba. *Small Ruminant Research, 210*, Article 106679. https://doi.org/10.1016/j.smallrumres.2022.106679

Carrara, E. R., Lopes, P. S., Reis, A. C. Z., Silva, J. X., Dias, L. C. C. M., Schultz, E. B., Marques, D. B. D., Silva, D. A., Veroneze, R., Andrade, R. G., & Peixoto, M. G. C. D. (2023). NASA POWER satellite meteorological system is a good tool for obtaining estimates of the temperature-humidity index under Brazilian conditions compared to INMET weather stations data. International Journal of Biometeorology, 67(7), 1273-1277. https://doi.org/10.1007/s00484-023-02493-5

Food and Agriculture Organization of the United Nations. (2023). Agricultural production statistics 2010-2024. https://www.fao.org/statistics/highlights-archive/highlights-detail/agricultural-production-statistics-2010-2024/en

Food and Agriculture Organization of the United Nations. (n.d.). *FAOSTAT*. https://www.fao.org/faostat/en/

Gershon, O., & Mbajekwe, C. (2020). Investigating the nexus of climate change and agricultural production in Nigeria. International Journal of Energy Economics and Policy, 10(6), 1-8. https://doi.org/10.32479/ijeep.9843

Godde, C. M., Mason-D'Croz, D., Mayberry, D. E., Thornton, P. K., & Herrero, M. (2021). Impacts of climate change on the livestock food supply chain. *Global Food Security, 28*, Article 100488. https://doi.org/10.1016/j.gfs.2020.100488

NASA Langley Research Center. (n.d.). *NASA Prediction of Worldwide Energy Resources (POWER)*. https://power.larc.nasa.gov/

Ogunlowo, Q. O., Azeez, A. A., Na, W. H., Rabiu, A., Adesanya, M. A., Zakir, E., Ijadunola, J. A., Afolabi, B. O., Kosemani, B. S., Ilori, T. A., & Lee, H.-W. (2024). Analysis of microclimate temperature and relative humidity distribution of local poultry house in a subtropical area of Nigeria. Journal of Agricultural Engineering, 55(2), Article 1561. https://doi.org/10.4081/jae.2024.1561

Ojo, O. A., Iyiola-Tunji, A. O., & Buba, W. (2024). Impact of climate change on livestock production in Nigeria: A review. Nigerian Journal of Animal Production, 770-774. https://doi.org/10.51791/njap.vi.5448

Omokaro, G. O. (2025). Multi-impacts of climate change and mitigation strategies in Nigeria: Agricultural production and food security. *Science in One Health, 4*, Article 100113. https://doi.org/10.1016/j.soh.2025.100113

Sejian, V. (2016). Impact of climate change on livestock productivity. Feedipedia. https://www.feedipedia.org/content/impact-climate-change-livestock-productivity

Sejian, V., Bhatta, R., Gaughan, J. B., Dunshea, F. R., & Lacetera, N. (2018). Review: Adaptation of animals to heat stress. *Animal, 12*(S2), s418-s430. https://doi.org/10.1017/S1751731118001945

Thornton, P., Nelson, G., Mayberry, D., & Herrero, M. (2022). Impacts of heat stress on global cattle production during the 21st century: A modelling study. *The Lancet Planetary Health, 6*(3), e192-e201. https://doi.org/10.1016/S2542-5196(22)00002-X

Yusuf, M., Swanson, K. C., Hulsman Hanna, L. L., Degges, R., & Bauer, M. L. (2022). Solar radiation and temperature as predictor variables for dry matter intake in beef steers. *Frontiers in Animal Science, 3*, Article 975093. https://doi.org/10.3389/fanim.2022.975093