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Statistical Analysis Of Climate Variability And Its Impact On Agricultural Productivity In Northern Nigeria: Evidence From Sokoto And Zamfara States

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ABSTRACT
This study examines the statistical relationship between climate variability and agricultural productivity in Northern Nigeria, with specific evidence from Sokoto and Zamfara States. The study is motivated by the growing concern that changes in rainfall patterns, increasing temperatures and recurrent dry spells may affect crop production and rural livelihoods in the semi-arid and Sudano-Sahelian environments of north-western Nigeria. The study adopts a quantitative, ex-post facto research design based principally on secondary time-series data on rainfall, temperature, dry-spell frequency and agricultural productivity, supplemented where available by agricultural input indicators such as fertilizer use and irrigation. Descriptive statistics, trend analysis, Pearson correlation, multiple regression and state-level analysis of variance are proposed for the empirical analysis. The Augmented Dickey-Fuller unit-root test will be used to establish the stationarity properties of the time-series variables, while an ARDL framework will be considered where the variables are integrated of mixed orders I(0) and I(1) and satisfy the required conditions. Existing evidence indicates that climate variability is an important risk to African food systems and that rain-fed agriculture is particularly exposed to rainfall and temperature changes (IPCC, 2022). Nigerian evidence also suggests that rainfall variability, irrigation and temperature conditions have measurable implications for agricultural production The study provide state-specific empirical evidence that can inform climate-smart agriculture, irrigation planning, agricultural extension, early-warning systems and adaptation policy in Sokoto and Zamfara States. The study's findings will contribute to the literature by linking climate indicators with agricultural productivity while accounting for selected production inputs.
Keywords: climate variability; rainfall; temperature; dry spells; agricultural productivity; Sokoto; Zamfara; Nigeria; ARDL; climate-smart agriculture.

INTRODUCTION

1.1 Background to the Study

Agriculture is highly sensitive to climatic conditions because crop growth, livestock production and agricultural water availability depend directly and indirectly on temperature, precipitation and the timing of weather events. Climate variability becomes particularly important in rain-fed systems because deviations from expected rainfall can affect planting dates, soil moisture, crop development and harvest outcomes. The Intergovernmental Panel on Climate Change (IPCC, 2022) reports that climate change is

already reducing agricultural productivity in Africa and that future warming is expected to increase water stress and shorten growing seasons in many parts of the continent.

Nigeria is especially relevant to this debate because agriculture remains a major source of employment, livelihoods and food supply, while much of agricultural production is rain-fed. The World Bank's Agro-Climatic Resilience in Semi-Arid Landscapes project notes that most agricultural land in the centre and north of Nigeria is rain-fed and identifies climate change, resource constraints, weak agricultural systems and limited irrigation as important barriers to higher productivity (World Bank, 2021). Nigerian research likewise finds that rainfall and irrigation have differential effects on agricultural production and that irrigation can reduce climate-induced production risks (Abdullahi et al., 2016).

The problem is especially pronounced in Northern Nigeria, where farming systems operate under relatively dry conditions and where rainfall is concentrated within a short agricultural season. In the Sudano-Sahelian zone, rainfall onset and cessation are critical for determining the length of the effective growing season. Atedhor (2020) found substantial variability in rainfall during the onset and cessation of the growing season across stations in the Sudano-Sahelian region, including Sokoto. Such variability can make farm planning difficult and can expose farmers to false onset, dry spells and shortened growing seasons.

Evidence from Sokoto also demonstrates the importance of examining climate variables jointly rather than assuming that total rainfall alone determines agricultural performance. Ikpe et al. (2021) analysed 48 years of rainfall, temperature and yield data for millet, maize and sorghum in Sokoto State and reported varying relationships between weather variables and crop yields. Their findings underscore the need for location-specific empirical analysis rather than relying solely on national averages.

Recent Nigerian literature further links climate variability with agricultural productivity, food security and livelihood vulnerability. Amare and Balana (2023), using nationally representative household data linked to long-term temperature and precipitation information, found that harmful heat exposure was associated with lower agricultural productivity. Similarly, recent reviews of Nigerian evidence identify erratic rainfall, rising temperatures, drought and floods as important pressures on agricultural production and food security (Omokaro, 2025).

Against this background, Sokoto and Zamfara States provide an important setting for empirical investigation. Both states are located in north-western Nigeria and contain substantial agricultural populations whose production is exposed to rainfall variability and high temperatures. The study therefore focuses on the statistical relationship between climate variability and agricultural productivity, while also considering irrigation and fertiliser use as potential production-supporting factors.

1.2 Statement of the Problem

Despite the importance of agriculture to livelihoods and food supply in Northern Nigeria, agricultural production continues to face climatic and non-climatic risks. Climate variability can manifest through delayed or early rainfall onset, changes in rainfall totals, uneven distribution of precipitation, prolonged dry spells, high temperatures, droughts and floods. In rain-fed farming systems, these conditions can disrupt planting calendars, reduce soil moisture and affect crop development. The problem is compounded by limited irrigation, input constraints, weak extension services, market difficulties and other socio-economic pressures (World Bank, 2021).

Existing empirical studies provide useful evidence but leave important gaps. Some studies focus on national agricultural output, while others examine individual crops or single climate indicators. For example, Ikpe et al. (2021) examined selected grain crops in Sokoto, while Abdullahi et al. (2016) considered rainfall and irrigation at the national level. These studies do not fully resolve the question of how a combination of rainfall, temperature and dry-spell conditions relates to aggregate agricultural productivity across Sokoto and Zamfara.

A further methodological problem arises when time-series variables are analysed without testing for stationarity. Climate and agricultural series may contain trends, and conventional regression using non-stationary variables can produce spurious statistical relationships. A rigorous study therefore needs to

combine descriptive and inferential analysis with unit-root testing and, where appropriate, a time-series framework capable of distinguishing short-run from long-run relationships.

The central problem addressed by this study is therefore the insufficiently integrated and state-specific empirical evidence on how climate variability affects agricultural productivity in Sokoto and Zamfara States. The study seeks to fill this gap by statistically examining rainfall, temperature and dry-spell frequency alongside agricultural productivity and selected agricultural inputs.

1.3 Objectives of the Study

The broad aim of the study is to statistically analyse `climate variability and its impact on agricultural productivity in Sokoto and Zamfara States of Northern Nigeria. The specific objectives are to:

1. examine the trend and variability of rainfall, temperature and dry-spell frequency in Sokoto and Zamfara States;
2. determine the relationship between rainfall variability and agricultural productivity in the study area;
3. assess the effect of temperature variability on agricultural productivity;
4. examine the effect of dry-spell frequency on agricultural productivity;
5. determine whether agricultural productivity differs significantly between Sokoto and Zamfara States;
6. assess the contribution of selected agricultural inputs, particularly fertilizer use and irrigation, to agricultural productivity; and
7. determine the stationarity properties of the study variables and identify an appropriate time-series modelling strategy.

1.4 Research Questions

2. How have rainfall, temperature and dry-spell conditions varied in Sokoto and Zamfara States?
3. What relationship exists between rainfall variability and agricultural productivity?
4. To what extent does temperature variability affect agricultural productivity?
5. What effect does dry-spell frequency have on agricultural productivity?
6. Is there a significant difference in agricultural productivity between Sokoto and Zamfara States?
7. To what extent do fertilizer use and irrigation contribute to agricultural productivity?
8. What are the stationarity properties of the study variables and what time-series model is appropriate for the analysis?

1.5 Research Hypotheses

2. H01: Climate variability has no statistically significant effect on agricultural productivity in Sokoto and Zamfara States.
3. H02: Rainfall variability has no statistically significant effect on agricultural productivity.
4. H03: Temperature variability has no statistically significant effect on agricultural productivity.
5. H04: Dry-spell frequency has no statistically significant effect on agricultural productivity.
6. H05: There is no statistically significant difference in agricultural productivity between Sokoto and Zamfara States.
7. H06: Fertilizer use and irrigation have no statistically significant effects on agricultural productivity.

1.6 Significance of the Study

The study is expected to be useful to policymakers, agricultural planners, climate agencies, researchers, farmers and development organisations. For policymakers in Sokoto and Zamfara States, the results can provide evidence for prioritising irrigation, climate information services and agricultural support programmes. For agricultural extension agencies, the findings can help identify climate risks that should be incorporated into farmer advisory services.

The study is also relevant to climate adaptation planning. Nigeria's National Climate Change Policy recognises that agriculture and food production systems are exposed to climate change and recommends measures including drought-resistant crop varieties, crop diversification, changes in planting calendars, soil-moisture conservation and improved irrigation (Federal Ministry of Environment, 2021). Empirical

evidence from the two study states can help translate such broad policy directions into more geographically relevant interventions.

Academically, the study contributes to the literature by combining climate indicators, agricultural productivity and selected production inputs in a single analytical framework and by explicitly considering the time-series properties of the data.

1.7 Scope of the Study

Geographically, the study covers Sokoto and Zamfara States in north-western Nigeria. Conceptually, it focuses on climate variability as represented primarily by rainfall, temperature and dry-spell frequency, and agricultural productivity as the principal outcome variable. Fertilizer use and irrigation are considered as control or complementary production variables. The study is designed primarily around secondary annual time-series data for a sufficiently long period to permit trend and econometric analysis. The exact study period will depend on the availability and consistency of the selected datasets.

LITERATURE REVIEW

2.1 Conceptual Review

2.1.1 Concept of Climate Variability

Climate variability refers to variations in the statistical characteristics of climate over periods ranging from seasons to decades. It differs from climate change, although the two concepts are related. Climate variability includes fluctuations in rainfall, temperature and other climatic elements around their long-term averages, while climate change refers to a long-term shift in climate characteristics. For agriculture, variability is important because farmers make production decisions within relatively short seasonal windows. A delayed rainy season or an unusually long dry spell can therefore have large consequences even when annual rainfall is close to its long-term average.

2.1.2 Rainfall Variability and Agriculture

Rainfall is one of the most important climatic determinants of agricultural production in rain-fed systems. Its amount, onset, cessation, intensity and intra-seasonal distribution affect soil moisture and crop water availability. In the Sudano-Sahelian region, rainfall onset and cessation influence the effective growing season (Atedhor, 2020). Consequently, agricultural effects may depend not only on annual rainfall totals but also on the timing and distribution of rainfall.

2.1.3 Temperature and Agriculture

Temperature influences crop development, evapotranspiration, photosynthesis and water requirements. Moderate temperature conditions can support crop growth, whereas excessive heat can create heat stress and reduce yields. Evidence from Nigeria shows that changes in harmful heat exposure can reduce agricultural productivity (Amare & Balana, 2023). The effect may also differ by crop and growth stage.

2.1.4 Dry Spells and Agricultural Productivity

Dry spells are periods of insufficient rainfall occurring within an otherwise active growing season. They can be especially damaging when they coincide with germination, flowering or grain filling. Research on north-western Nigeria has found negative relationships between dry-spell conditions and yields of several crops, reinforcing the importance of intra-seasonal rainfall distribution (Ibrahim et al., 2014).

2.1.5 Agricultural Productivity

Agricultural productivity generally refers to the efficiency with which agricultural inputs are transformed into output. It can be measured using output per hectare, crop yield, labour productivity, total factor productivity or related indicators. For this study, the selected productivity measure will depend on the consistency and availability of historical agricultural data for the two states.

2.1.6 Irrigation, Fertilizer and Climate Adaptation

Irrigation can reduce farmers' dependence on uncertain rainfall and can support production during dry periods. Evidence from Nigeria indicates that irrigation has a positive and significant relationship with agricultural production across several agricultural subsectors (Abdullahi et al., 2016). Fertiliser can also increase yields by improving nutrient availability, although its effectiveness depends on water availability,

soil conditions and management. Climate adaptation therefore requires complementary interventions rather than reliance on a single input.

2.2 Theoretical Review

2.2.1 Production Function Theory

The study is primarily anchored in production function theory. In its basic form, agricultural output is a function of inputs such as land, labour, capital and technology. Climate can be incorporated as an environmental or quasi-input that affects the productivity of conventional agricultural inputs. A simplified production relationship can be expressed as:

$Y = f(L, K, A, W, C, T)$

where Y represents agricultural output or productivity; L represents labour; K represents capital and other physical inputs; A represents agricultural inputs and management; W represents water availability/irrigation; C represents climate conditions; and T represents technology. The framework is useful because it permits rainfall, temperature and dry spells to enter the productivity relationship while allowing fertiliser and irrigation to operate as complementary production factors.

2.2.2 Ricardian Approach to Climate and Agriculture

The Ricardian approach evaluates climate effects through the value or productivity of agricultural land. Its central insight is that farmers' observed choices and land values reflect adaptation to local climate conditions. The approach is useful for understanding how farmers adjust production systems to different climatic environments, although a purely time-series study may use a more direct production-function specification.

2.2.3 Sustainable Livelihoods and Climate Vulnerability Perspective

The sustainable livelihoods perspective emphasises that climate shocks interact with households' assets, institutions and adaptive capacity. Farmers with irrigation, credit, extension, information and diversified livelihoods may be better positioned to cope with climate variability than households with limited assets. This perspective complements the production-function approach by explaining why the same climatic shock may have different effects across locations and farming households.

2.3 Empirical Review

Empirical research increasingly demonstrates that climate variability affects agricultural production across Africa. The IPCC (2022) reports high-confidence evidence that climate change has reduced agricultural productivity growth in Africa and that future warming is expected to increase water stress and reduce yields for several staple crops. The assessment also highlights the importance of adaptation measures such as irrigation, altered planting dates and improved cultivars.

In Nigeria, Abdullahi et al. (2016) examined the differential effects of rainfall and irrigation on agricultural production using long-run time-series data. Their results indicated that irrigation had positive and significant effects on aggregate agricultural production and several subsectors, supporting the view that complementary water management can reduce climate risk.

Atedhor (2020) investigated rainfall variability during the onset and cessation of the growing season in the Sudano-Sahelian region of Nigeria using long-term rainfall records. The study demonstrated that rainfall conditions at the beginning and end of the growing season vary across locations, with implications for agricultural planning.

Ikpe et al. (2021) examined rainfall and temperature variability and yields of millet, maize and sorghum in Sokoto State using 48 years of data. Their findings showed crop-specific relationships and recommended improved varieties and adaptation measures. This is particularly relevant to the present study because it demonstrates that the climate-productivity relationship in Sokoto cannot necessarily be inferred from national-level results.

Amare and Balana (2023) used Nigerian household and long-term climate data to investigate climate change, crop mix, input use and agricultural productivity. They found that greater exposure to harmful heat was associated with lower agricultural productivity. Their findings reinforce the need to include temperature measures in empirical models rather than focusing exclusively on rainfall.

Recent reviews also conclude that erratic rainfall, increasing temperatures, droughts and floods pose substantial risks to Nigerian agricultural production and food security (Omokaro, 2025). These studies collectively suggest that climate effects are context-specific and may depend on agricultural inputs, adaptation and local environmental conditions.

2.4 Gap in the Literature

Three principal gaps motivate the present study. First, relatively few studies jointly examine rainfall, temperature and dry-spell frequency in relation to agricultural productivity in both Sokoto and Zamfara. Second, much of the existing evidence either focuses on individual crops, individual states or national aggregates, limiting the ability to compare nearby north-western states within a common analytical framework. Third, some analyses do not sufficiently integrate stationarity testing and time-series model selection into the empirical strategy.

The present study addresses these gaps by using a comparative state-level framework, combining climate indicators with selected agricultural inputs and incorporating unit-root testing and appropriate time-series modelling where the data properties require it.

2.5 Conceptual Framework

The conceptual framework assumes that climate variability affects agricultural productivity directly and indirectly through water availability, crop stress and farmers' production decisions.

Independent Variables	Intervening/Control Factors	Dependent Variable
Rainfall variability	Irrigation	Agricultural productivity
Temperature variability	Fertiliser use	Crop yield/output
Dry-spell frequency	Agricultural technology	
Climate extremes	Extension/adaptation	

Source: Author's conceptualization, 2026.

The framework predicts that adequate rainfall supports productivity, while excessive temperature and frequent dry spells reduce productivity. Irrigation, fertilizer use and adaptation practices are expected to moderate or partly offset adverse climate effects.

METHODOLOGY

3.1 Research Design

The study adopts a quantitative ex-post facto research design. The design is appropriate because the principal climate and agricultural variables have already occurred and cannot be manipulated by the researcher. The study relies on historical time-series observations and applies statistical and econometric techniques to estimate relationships among the variables.

3.2 Area of the Study

The study area comprises Sokoto and Zamfara States in north-western Nigeria. The two states form part of the Sudan and Sahel-influenced ecological environment and experience a pronounced wet and dry seasonal cycle. Agricultural production includes rain-fed and irrigated farming, with crops such as millet, sorghum, maize, rice and other staples cultivated in different locations. Their climatic setting makes them suitable for studying rainfall variability, temperature and dry spells.

Sokoto State lies in the north-western part of Nigeria and shares borders with Niger Republic as well as Kebbi and Zamfara States. Zamfara borders Sokoto, Kebbi, Katsina, Kaduna and Niger State. The study treats the two states as separate analytical units while also examining pooled relationships where data permit.

3.3 Sources of Data

The study will use secondary data obtained from reliable institutional and published sources. Climate data may be obtained from the Nigerian Meteorological Agency (NiMet), national or international climate databases, and other validated datasets where station records are incomplete. Agricultural productivity and production data may be obtained from the National Bureau of Statistics, Federal Ministry of Agriculture and Food Security, state agricultural development agencies, FAOSTAT and other recognised agricultural

databases. Data on irrigation and fertiliser use will be obtained from official agricultural statistics where consistent annual series are available.

The choice of the final period will be determined by the availability of continuous and comparable observations. Data definitions and units will be harmonised before estimation, and missing observations will be documented rather than silently imputed.

3.4 Population and Unit of Analysis

Because the study is based on secondary time-series data rather than a questionnaire survey, the statistical population consists of the available annual observations for the selected variables in Sokoto and Zamfara States over the study period. The primary unit of analysis is the state-year observation. Where station-level climate data are used, station observations will be aggregated or otherwise matched to the corresponding state and agricultural period using a transparent procedure.

3.5 Measurement of Variables

Variable	Symbol	Measurement/Proxy	Expected Effect
Agricultural productivity	AP	Output/yield per hectare or consistent productivity index	Dependent
Rainfall	RF	Annual or growing-season rainfall (mm)	Positive, subject to nonlinearity
Temperature	TEMP	Mean or growing-season temperature (°C)	Negative at high levels
Dry-spell frequency	DS	Number/duration of significant dry spells during growing season	Negative
Fertiliser use	FERT	Fertiliser use per hectare or consistent annual indicator	Positive
Irrigation	IRR	Irrigated area or irrigation index	Positive

Source: Author's operationalisation, 2026.

3.6 Model Specification

The baseline empirical model is specified as:

$$AP_t = \beta_0 + \beta_1 RF_t + \beta_2 TEMP_t + \beta_3 DS_t + \beta_4 FERT_t + \beta_5 IRR_t + \varepsilon_t$$

where AP is agricultural productivity; RF is rainfall; TEMP is temperature; DS is dry-spell frequency; FERT is fertiliser use; IRR is irrigation; β_0 is the intercept; β_1–β_5 are slope coefficients; and ε is the stochastic error term.

The expected signs are $\beta_1 > 0$, $\beta_2 < 0$, $\beta_3 < 0$, $\beta_4 > 0$ and $\beta_5 > 0$, although the empirical results will determine whether these expectations are supported. If diagnostic and stationarity tests indicate that a dynamic specification is necessary, the study will extend the analysis using an ARDL model.

3.7 Time-Series and ADF Testing

Before estimating long-run relationships, the study will test the stationarity of each series using the Augmented Dickey-Fuller (ADF) test. The null hypothesis of the ADF test is that the series contains a unit root. If the test statistic is more negative than the relevant critical value, or if the p-value is below the selected significance level, the null hypothesis will be rejected.

Where variables are stationary at level I(0) or become stationary after first differencing I(1), but none is I(2), an ARDL approach may be considered. The bounds-testing procedure can then be used to determine whether a long-run relationship exists. If the variables are all stationary at level, a standard regression or other appropriate time-series model may be used, subject to diagnostic testing.

3.8 Descriptive and Inferential Analysis

Descriptive statistics will include the mean, minimum, maximum and standard deviation. Trend analysis will be used to examine the direction of climate and productivity changes over time. Pearson correlation will provide an initial assessment of the direction and strength of bivariate associations. Multiple regression will estimate the partial effect of the explanatory variables on agricultural productivity.

An independent-samples comparison or one-way ANOVA, depending on the final structure of the dataset, will be used to test whether productivity differs significantly between Sokoto and Zamfara. For the time-series component, ADF tests will precede the final dynamic specification.

3.9 Diagnostic Tests

To improve the reliability of the estimated coefficients, the study will examine multicollinearity, heteroskedasticity, autocorrelation and model specification. Variance Inflation Factor (VIF) values will be considered when assessing multicollinearity. Residual diagnostics such as the Breusch-Pagan or related heteroskedasticity test may be employed. Serial correlation will be assessed using an appropriate test such as the Breusch-Godfrey LM test or Durbin-Watson statistic, depending on the final model. Normality of residuals may also be assessed descriptively, although inference will not rely solely on a normality test.

3.10 Decision Rule for Hypotheses

The hypotheses will be tested at the 5% level of significance. A null hypothesis will be rejected when the probability value is less than 0.05. When the p-value is greater than or equal to 0.05, the null hypothesis will not be rejected. The direction and magnitude of coefficients will also be considered because statistical significance alone does not establish substantive importance.

3.11 Validity and Reliability of Data

Data validity will be enhanced through the use of recognised institutional sources and peer-reviewed literature. Where multiple sources provide the same climate variable, the study will compare units, measurement periods and definitions before selecting the series. Reliability will be improved through consistency checks, graphical inspection and documentation of missing or revised observations.

3.12 Ethical Considerations

The study uses secondary aggregate data and does not require the collection of identifiable personal information. Proper acknowledgement will be given to data providers and published sources. Data will not be altered to produce desired results, and any cleaning, transformation or exclusion of observations will be transparently reported.

3.13 Methodological Limitations

The study face limitations associated with missing observations, changes in statistical definitions, differences in climate-station coverage and the availability of consistent state-level agricultural productivity data. Agricultural output is also affected by non-climatic factors such as pests, input prices, insecurity, land quality and market conditions that may not be fully captured in the model. These limitations will be acknowledged when interpreting the results.

4. DATA PRESENTATION, ANALYSIS AND DISCUSSION OF RESULTS

4.1 Introduction

This chapter presents the statistical analysis of the relationship between climate variability and agricultural productivity in Sokoto and Zamfara States, Northern Nigeria. The analysis is structured around the objectives and hypotheses of the study. Descriptive statistics are first presented to examine the characteristics and patterns of the major variables. This is followed by correlation analysis to determine the direction and strength of the relationships between climate variables and agricultural productivity. Regression analysis is subsequently employed to estimate the effect of rainfall, temperature and dry-spell frequency on agricultural productivity while controlling for selected agricultural factors. Analysis of variance (ANOVA) is used to examine differences between the two states, while the Augmented Dickey-Fuller (ADF) test is employed to assess the stationarity of the time-series variables. The results presented in this chapter are simulated for prototype purposes and are intended to demonstrate the anticipated empirical structure of the study.

4.2 Descriptive Statistics

The descriptive statistics provide an overview of the distribution of the variables used in the study. The principal variables include annual rainfall, mean temperature, frequency of dry spells and agricultural productivity. Fertiliser use and irrigation are included as control variables because agricultural productivity is influenced not only by climatic conditions but also by farmers' production practices.

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Annual Rainfall (mm)	60	420.20	910.80	650.40	115.60
Mean Temperature (°C)	60	27.60	32.40	29.80	1.21
Dry-Spells Frequency	60	2.00	10.00	5.70	2.14
Agricultural Productivity	60	0.82	2.15	1.42	0.38
Fertiliser Use	60	35.00	125.00	74.60	21.45
Irrigation Index	60	15.00	82.00	43.80	16.72

Source: Simulated SPSS Output, 2026.

The results indicate substantial variation in the climatic and agricultural variables. Annual rainfall has a mean of 650.40 mm, with a standard deviation of 115.60 mm, suggesting considerable year-to-year variability. Mean temperature is 29.80°C, while the frequency of dry spells averages 5.70 occurrences. Agricultural productivity has a mean value of 1.42 tonnes per hectare. The relatively large standard deviation associated with rainfall suggests that agricultural production in the study area may be exposed to considerable rainfall uncertainty. Similarly, variation in dry-spell frequency indicates that the timing and availability of rainfall may be an important determinant of crop performance.

4.3 Trend Analysis of Climate Variables and Agricultural Productivity

The study is expected to demonstrate that climatic conditions have changed over the period under investigation. In particular, temperature is expected to exhibit an upward trend, while rainfall demonstrates greater inter-annual fluctuations. The illustrative trend suggests that increasing temperature may coincide with declining agricultural productivity. Nevertheless, such a pattern should not be interpreted as causal until the regression and time-series analyses have controlled for other relevant factors.

4.4 Correlation Analysis

Pearson correlation analysis was conducted to determine the direction and strength of the relationships between climate variability and agricultural productivity.

Variables	Rainfall	Temperature	Dry Spells	Productivity
Rainfall	1.000	-0.214	-0.461**	0.438**
Temperature	-0.214	1.000	0.397**	-0.512**
Dry Spells	-0.461**	0.397**	1.000	-0.476**
Agricultural Productivity	0.438**	-0.512**	-0.476**	1.000

Note: **$p < 0.01$ (two-tailed). Source: Simulated SPSS Output, 2026.

The correlation results indicate a positive relationship between rainfall and agricultural productivity ($r = 0.438$, $p < 0.01$). This suggests that increased and adequate rainfall is associated with higher agricultural productivity. Temperature has a negative and significant relationship with agricultural productivity ($r = -0.512$, $p < 0.01$). Similarly, dry-spell frequency is negatively associated with agricultural productivity ($r = -0.476$, $p < 0.01$). These findings provide preliminary evidence that climatic instability may adversely affect agricultural output in the study area.

4.5 Multiple Regression Analysis

Multiple regression analysis was employed to determine the effect of climate variability on agricultural productivity while controlling for fertiliser use and irrigation.

$AP = \beta_0 + \beta_1 RF + \beta_2 TEMP + \beta_3 DS + \beta_4 FERT + \beta_5 IRR + \varepsilon$

Where AP = Agricultural Productivity; RF = Rainfall; TEMP = Temperature; DS = Dry-spell frequency; FERT = Fertiliser use; IRR = Irrigation; and ε = Error.

Model	R	R^2	Adjusted R^2	Std. Error of Estimate
1	0.762	0.581	0.542	0.249

Source: Simulated SPSS Output, 2026.

The model produces an R^2 of 0.581, indicating that approximately 58.1% of the variation in agricultural productivity is explained jointly by rainfall, temperature, dry-spell frequency, fertiliser use and irrigation. The adjusted R^2 of 0.542 indicates that the explanatory power remains substantial after accounting for the number of predictors.

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	11.532	5	2.306	18.64	<0.001
Residual	8.900	54	0.165		
Total	20.432	59			

Source: Simulated SPSS Output, 2026.

The ANOVA result shows that the overall regression model is statistically significant ($F = 18.64$, $p < 0.001$). Thus, the explanatory variables jointly provide a statistically significant explanation of variations in agricultural productivity.

Variable	B	Std. Error	Beta	t	Sig.
Constant	2.184	0.481	—	4.54	<0.001
Rainfall	0.318	0.081	0.341	3.93	<0.001
Temperature	-0.427	0.094	-0.389	-4.54	<0.001
Dry-Spells Frequency	-0.265	0.073	-0.318	-3.63	0.001
Fertiliser Use	0.186	0.067	0.201	2.78	0.006
Irrigation	0.291	0.082	0.278	3.55	0.001

Source: Simulated SPSS Output, 2026.

The results indicate that rainfall has a positive and statistically significant effect on agricultural productivity ($\beta = 0.341$, $p < 0.001$). Temperature has a negative and significant effect ($\beta = -0.389$, $p < 0.001$), while dry-spell frequency also has a significant negative effect ($\beta = -0.318$, $p = 0.001$). Among the control variables, fertilizer use and irrigation are both positively associated with agricultural productivity. This suggests that appropriate agricultural inputs and irrigation may partly offset the adverse effects of climatic variability.

4.6 State-Level ANOVA

A one-way ANOVA can be used to determine whether agricultural productivity differs significantly between Sokoto and Zamfara States.

State	N	Mean Productivity	Std. Deviation
Sokoto	30	1.31	0.31
Zamfara	30	1.53	0.40
Total	60	1.42	0.38

Source	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	0.726	1	0.726	5.21	0.026
Within Groups	8.365	58	0.144		
Total	9.091	59			

Source: SPSS Output, 2026.

The s ANOVA result indicates a statistically significant difference in agricultural productivity between Sokoto and Zamfara States ($F = 5.21$, $p = 0.026$). Zamfara records a higher mean productivity than Sokoto in the illustrative dataset. This difference may reflect variations in rainfall conditions, access to irrigation, agricultural practices, soil characteristics, crop composition and farmers' adaptive capacity. However, these possible explanations would require further empirical investigation.

4.7 Augmented Dickey-Fuller (ADF) Unit Root Test

Since the study involves climatic and agricultural time-series data, it is important to establish whether the variables are stationary before estimating time-series relationships. The Augmented Dickey-Fuller test is therefore applied.

Variable	ADF Statistic at Level	5% Critical Value	p-value	Order of Integration
Agricultural Productivity	-3.821	-2.976	0.004	I(0)
Rainfall	-2.431	-2.976	0.137	I(1)
Temperature	-2.214	-2.976	0.201	I(1)
Dry-Spells Frequency	-3.147	-2.976	0.028	I(0)
Rainfall (First Difference)	-4.673	-2.981	<0.001	I(1)
Temperature (First Difference)	-4.216	-2.981	0.002	I(1)

Source: EViews/SPSS-compatible time-series output, 2026.

The ADF results indicate that agricultural productivity and dry-spell frequency are stationary at level, while rainfall and temperature become stationary after first differencing. The variables are therefore integrated of mixed orders, I(0) and I(1). This finding would make an ARDL (Autoregressive Distributed Lag) model potentially appropriate, provided the actual dataset satisfies the required conditions. The study should avoid applying ordinary regression mechanically to non-stationary variables because this can produce misleading or spurious relationships.

4.8 Hypothesis Testing

Hypothesis	Statistical Evidence	Decision
H01: Climate variability has no significant effect on agricultural productivity.	$F = 18.64$, $p < 0.001$	Reject H01
H02: Rainfall variability has no significant effect on agricultural productivity.	$\beta = 0.341$, $p < 0.001$	Reject H02
H03: Temperature variability has no significant effect on agricultural productivity.	$\beta = -0.389$, $p < 0.001$	Reject H03
H04: Dry-spell frequency has no significant effect on agricultural productivity.	$\beta = -0.318$, $p = 0.001$	Reject H04
H05: There is no significant difference in agricultural productivity between Sokoto and Zamfara States.	$F = 5.21$, $p = 0.026$	Reject H05

4.9 DISCUSSION OF FINDINGS

4.9.1 Climate Variability and Agricultural Productivity

The expected empirical findings indicate that climate variability significantly affects agricultural productivity in Sokoto and Zamfara States. The regression results suggest that approximately 58.1% of variations in agricultural productivity can be explained by the climatic and agricultural variables included in the model. This demonstrates the importance of climatic conditions in determining agricultural outcomes in Northern Nigeria.

4.9.2 Rainfall and Agricultural Productivity

The positive coefficient for rainfall suggests that increased rainfall is associated with improved agricultural productivity, assuming that rainfall remains within an agriculturally beneficial range. Adequate rainfall improves soil moisture and supports crop growth, particularly among farmers who depend primarily on rain-fed agriculture. However, the positive relationship should not be interpreted to mean that unlimited rainfall improves productivity. Excessive rainfall may result in flooding, waterlogging, erosion and crop damage. The actual relationship should therefore be examined for possible nonlinear effects.

4.9.3 Temperature and Agricultural Productivity

The negative coefficient for temperature indicates that rising temperatures may reduce agricultural productivity. Higher temperatures can increase evapotranspiration and crop water requirements while reducing available soil moisture. The result is particularly relevant to farming communities that have limited access to irrigation. Where farmers cannot compensate for higher temperatures through irrigation or other adaptation measures, increased heat stress may contribute to declining yields.

4.9.4 Dry Spells and Agricultural Productivity

The negative relationship between dry spells and agricultural productivity indicates that prolonged interruptions in rainfall can adversely affect agricultural output. Dry spells occurring during critical stages such as germination, flowering and grain filling can cause substantial yield losses even where total seasonal rainfall is not exceptionally low. Consequently, the study is expected to demonstrate that rainfall distribution may be as important as total rainfall volume when evaluating climate impacts on agriculture.

4.9.5 Irrigation and Agricultural Adaptation

The positive coefficient for irrigation suggests that access to irrigation can improve agricultural productivity and potentially reduce farmers' vulnerability to rainfall variability. This indicates that adaptation strategies may play an important role in reducing the adverse effects of climatic variability. The implication is that climate adaptation policies should not focus exclusively on climate forecasting. Investment in irrigation infrastructure, drought-resistant crop varieties, water management and extension services may be equally important.

4.10 Summary of Major Findings

- Climate conditions exhibit substantial variability across the study period.
- Rainfall has a positive and significant relationship with agricultural productivity.
- Temperature has a negative and significant effect on agricultural productivity.
- Dry-spell frequency significantly reduces agricultural productivity.
- Fertilizer use and irrigation are expected to positively influence agricultural productivity.
- Climate and agricultural variables jointly explain a substantial proportion of variations in agricultural productivity.
- Agricultural productivity is expected to differ significantly between Sokoto and Zamfara States.

The ADF results suggest that some variables may be stationary at level while others become stationary after first differencing, making appropriate time-series techniques necessary.

Overall, the findings demonstrate that climate variability represents a significant challenge to agricultural productivity in Northern Nigeria.

4.11 Conclusion

The findings suggest that agricultural productivity in Sokoto and Zamfara States is significantly influenced by climatic variability, particularly rainfall, temperature and dry-spell frequency. The expected

negative effects of increasing temperature and prolonged dry spells underscore the vulnerability of agricultural production to climate-related shocks. At the same time, the positive contribution of irrigation and fertilizer use suggests that appropriate adaptation and agricultural-input strategies can moderate the adverse effects of climatic variability. The empirical evidence would therefore support increased investment in climate-smart agriculture, irrigation development, improved weather information systems, drought-tolerant crops and agricultural extension services in Northern Nigeria.

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter presents the summary, conclusion and recommendations arising from the statistical analysis of climate variability and its impact on agricultural productivity in Northern Nigeria, with particular evidence from Sokoto and Zamfara States. The chapter draws on the prototype empirical results presented in Chapter Four. The discussion focuses on the major findings relating to rainfall, temperature, dry-spell frequency and agricultural productivity, as well as the role of fertiliser use and irrigation. The chapter concludes by outlining policy and practical recommendations aimed at strengthening agricultural resilience to climate variability in the study area. Because the results in Chapter Four were simulated for prototype purposes, the conclusions and recommendations presented here should be revised where necessary after the actual dataset has been analysed.

5.2 Summary of the Study

The study examined the statistical relationship between climate variability and agricultural productivity in Northern Nigeria, focusing on Sokoto and Zamfara States. The study was motivated by the increasing concern that changes and fluctuations in rainfall, temperature and dry spells may undermine agricultural production, particularly in areas where farming is heavily dependent on seasonal rainfall. The study therefore sought to provide empirical evidence on how climatic conditions influence agricultural productivity and to identify possible agricultural factors that can reduce farmers' vulnerability to climate-related shocks.

The study adopted a quantitative research approach involving descriptive statistics, correlation analysis, multiple regression, analysis of variance and the Augmented Dickey-Fuller unit-root test. Rainfall, temperature and dry-spell frequency were treated as the principal climate variables, while agricultural productivity served as the dependent variable. Fertiliser use and irrigation were incorporated as control variables to account for non-climatic influences on agricultural production. The analytical framework was designed to establish both the direction and statistical significance of the relationships among the variables.

5.3 Summary of Major Findings

5.3.1 Climate Variability in the Study Area

The descriptive results indicate substantial variability in climatic conditions during the period under consideration. Rainfall demonstrated considerable year-to-year fluctuations, while mean temperature showed an upward tendency. The frequency of dry spells also varied considerably. These patterns suggest that farmers in Sokoto and Zamfara operate within an increasingly uncertain climatic environment in which the timing, amount and distribution of rainfall may be as important as total annual rainfall.

5.3.2 Rainfall and Agricultural Productivity

The correlation and regression results indicate a positive and statistically significant relationship between rainfall and agricultural productivity. The prototype regression coefficient for rainfall was positive ($\beta = 0.341$, $p < 0.001$). This suggests that adequate rainfall contributes positively to agricultural productivity, particularly in rain-fed farming systems. The finding also indicates that fluctuations in rainfall availability can have important implications for crop performance.

5.3.3 Temperature and Agricultural Productivity

Temperature was found to have a negative and statistically significant relationship with agricultural productivity. The prototype regression result produced a standardised coefficient of $\beta = -0.389$ ($p < 0.001$). This suggests that increasing temperatures may reduce agricultural productivity through higher evapotranspiration, increased crop water requirements and heat stress. The result highlights the importance of temperature management and adaptation measures in agricultural planning.

5.3.4 Dry Spells and Agricultural Productivity

The study also found a negative and statistically significant relationship between dry-spell frequency and agricultural productivity. The prototype coefficient was $\beta = -0.318$ ($p = 0.001$). This indicates that prolonged interruptions in rainfall can adversely affect crop development, especially when dry spells occur during sensitive stages such as germination, flowering and grain formation. Thus, agricultural vulnerability is influenced not only by the quantity of rainfall but also by its temporal distribution.

5.3.5 Role of Fertilizer and Irrigation

The findings indicate that fertilizer use and irrigation have positive relationships with agricultural productivity. The prototype coefficients were $\beta = 0.201$ for fertilizer use and $\beta = 0.278$ for irrigation. These results suggest that improved access to agricultural inputs and irrigation can contribute to higher productivity and may provide farmers with greater capacity to adapt to changing climatic conditions.

5.3.6 Differences between Sokoto and Zamfara States

The state-level analysis indicated a statistically significant difference in agricultural productivity between Sokoto and Zamfara States in the simulated results. The ANOVA produced $F = 5.21$ and $p = 0.026$, with the illustrative mean productivity being higher in Zamfara than in Sokoto. This difference may reflect variations in rainfall conditions, irrigation access, agricultural practices, soil characteristics, crop composition and farmers' adaptive capacity. The actual reasons for any observed state difference should be established from the real data rather than assumed.

5.3.7 Overall Model Performance

The multiple regression model produced an illustrative R^2 of 0.581 and an adjusted R^2 of 0.542. This indicates that approximately 58.1 percent of the variation in agricultural productivity was explained jointly by rainfall, temperature, dry-spell frequency, fertilizer use and irrigation. The overall regression model was statistically significant ($F = 18.64$, $p < 0.001$), suggesting that the selected explanatory variables collectively provide a meaningful explanation of agricultural productivity in the study area.

5.3.8 Stationarity of the Variables

The prototype ADF results showed that the variables do not necessarily share the same order of integration. Agricultural productivity and dry-spell frequency were stationary at level, whereas rainfall and temperature became stationary after first differencing. This indicates the need for appropriate time-series procedures when analysing the actual data. If the final dataset confirms a mixture of I(0) and I(1) variables, an ARDL approach may be appropriate, subject to confirmation of the underlying assumptions and the absence of I(2) variables.

5.4 Conclusion

Based on the prototype empirical evidence, the study concludes that climate variability is an important determinant of agricultural productivity in Sokoto and Zamfara States. Variations in rainfall, increasing temperature and recurrent dry spells have important implications for agricultural production, especially among farmers who depend on rain-fed agriculture. The findings suggest that climatic conditions cannot be considered independently of agricultural productivity when developing policies for Northern Nigeria.

The study further concludes that rainfall availability is positively associated with agricultural productivity, whereas excessive temperature and frequent dry spells are likely to reduce agricultural output. At the same time, the positive contribution of irrigation and fertiliser use indicates that farmers' adaptive capacity can influence the severity of climate-related impacts. Agricultural productivity should therefore be understood as the outcome of an interaction between climatic conditions, production inputs, infrastructure and farmers' adaptation decisions.

Overall, the findings support a shift from a predominantly reactive approach to agricultural climate risk toward a more proactive and climate-resilient agricultural strategy. Such a strategy should combine improved climate information, irrigation development, appropriate agricultural inputs, climate-smart farming practices and stronger extension services. However, because the empirical statistics presented in this prototype are simulated, the final conclusion must be based on the magnitude, direction and statistical significance of the results obtained from the actual dataset.

5.5 Recommendations

Expansion of irrigation infrastructure: Government at federal and state levels should prioritise the development and rehabilitation of small-scale and large-scale irrigation facilities in suitable agricultural communities.

Improved access to irrigation can reduce farmers' dependence on uncertain rainfall and help maintain production during dry spells.

Promotion of climate-smart agriculture: Farmers should be encouraged and supported to adopt climate-smart practices such as conservation agriculture, improved soil-moisture management, mulching, appropriate planting dates, crop diversification and efficient water management.

Development and dissemination of climate information: Meteorological and agricultural institutions should strengthen the provision of timely, localised and easily understandable weather and seasonal climate information. Farmers should receive information on expected rainfall onset, dry spells, temperature conditions and possible extreme weather events.

Promotion of drought- and heat-tolerant crop varieties: Agricultural research institutions and extension agencies should increase the development and distribution of crop varieties that can tolerate drought, heat and short periods of moisture stress while remaining suitable for local farming systems.

Strengthening agricultural extension services: Extension officers should provide practical guidance on climate adaptation, water conservation, improved planting calendars, soil management, crop selection and efficient use of fertiliser and other agricultural inputs.

Improved access to agricultural inputs: Farmers should have better access to quality seeds, fertiliser, farm machinery and other inputs at affordable prices. Input-support programmes should be better targeted towards smallholder farmers who are most vulnerable to climate variability.

Climate-risk financing and agricultural insurance: Government and financial institutions should expand affordable agricultural insurance, climate-risk financing and other financial mechanisms that can help farmers recover from droughts, excessive rainfall and other climate-related production shocks.

Strengthening climate and agricultural data systems: Relevant institutions should improve the collection and integration of long-term rainfall, temperature, crop-yield, soil, irrigation and farm-level data. Reliable datasets are essential for monitoring climate impacts and designing evidence-based agricultural policy.

State-specific adaptation planning: Because climatic conditions and agricultural systems differ between Sokoto and Zamfara, adaptation policies should be tailored to the specific climatic, ecological and socio-economic characteristics of each state rather than applying a uniform strategy across the region.

Greater investment in climate-resilient rural infrastructure: Investments in rural roads, storage facilities, water systems, market infrastructure and post-harvest technologies should be strengthened because climate shocks can compound existing production and marketing constraints.

5.6 Contribution to Knowledge

The study contributes to knowledge by providing a statistical framework for examining the relationship between climate variability and agricultural productivity in two important states of Northern Nigeria. It brings together climatic variables and agricultural production factors within a single empirical framework, thereby moving beyond a purely descriptive assessment of climate change. The inclusion of rainfall, temperature and dry-spell frequency provides a broader assessment of climate variability, while the consideration of irrigation and fertiliser use recognises the role of adaptation and production inputs.

The study also contributes methodologically by combining descriptive statistics, correlation, regression, ANOVA and unit-root testing. This approach can provide a stronger empirical basis for understanding the short- and potentially long-term implications of climate variability for agriculture in Northern Nigeria.

5.7 Limitations of the Study

The study may be constrained by the availability, consistency and spatial resolution of long-term climate and agricultural data. Agricultural productivity can also be affected by factors that are difficult to measure statistically, including pests, diseases, access to credit, farm management practices, soil quality, security conditions and market prices. In addition, climate-productivity relationships may vary by crop, season and location. These limitations should be recognised when interpreting the empirical results.

A further limitation concerns the use of aggregate climate data. State-level or station-level averages may conceal important differences between local government areas and farming communities. Future studies should therefore consider more disaggregated spatial data and crop-specific productivity measures where such information is available.

5.9 Final Conclusion

The central conclusion of this study is that climate variability represents a significant challenge to agricultural productivity in Northern Nigeria, with important implications for farmers in Sokoto and Zamfara States. The prototype empirical results indicate that rainfall, temperature and dry-spell frequency significantly influence agricultural productivity, while irrigation and appropriate agricultural inputs can contribute to improved production outcomes. Addressing the agricultural consequences of climate variability therefore requires coordinated interventions involving climate information, irrigation, agricultural research, extension services, infrastructure, finance and farmer support.

The evidence further suggests that climate adaptation should be integrated into agricultural development planning rather than treated as a separate environmental issue. Strengthening the resilience of farmers will be essential for maintaining food production, rural livelihoods and agricultural income in the face of increasing climatic uncertainty. The final empirical conclusions, however, should be based strictly on the results obtained from the actual dataset and appropriate statistical tests.

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REFERENCES

Abdullahi, A. N., Akpoko, J. G., & Umar, H. S. (2016). Differential impacts of rainfall and irrigation on agricultural production in Nigeria: Any lessons for climate-smart agriculture? Agricultural Water Management, 178, 30–36. https://doi.org/10.1016/j.agwat.2016.08.034

Amare, M., & Balana, B. (2023). Climate change, income sources, crop mix, and input use decisions: Evidence from Nigeria. Ecological Economics, 211, 107892. https://doi.org/10.1016/j.ecolecon.2023.107892

Atedhor, G. O. (2020). Rainfall variability during onset and cessation of the growing season in the Sudano-Sahelian region of Nigeria. Journal of Geography, Meteorology and Environment.

Federal Ministry of Environment. (2021). National Climate Change Policy for Nigeria 2021–2030. Federal Republic of Nigeria.

Ikpe, E., Sawa, B. A., Ariko, J. D., Abdulhamid, A. I., & Akpu, B. (2021). Relationship between rainfall and temperature variability and the yields of selected grain crops in Sokoto State, Nigeria. Osun Geographical Review, 4(1).

Intergovernmental Panel on Climate Change (IPCC). (2022). Climate change 2022: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report. Cambridge University Press. https://doi.org/10.1017/9781009325844

Ibrahim, S. A., et al. (2014). Rainfall variability and crop production in the north-western semi-arid zone of Nigeria. Journal of Soil Science and Environmental Management.

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

World Bank. (2021). Nigeria Agro-Climatic Resilience in Semi-Arid Landscapes (ACReSAL) Project. World Bank.