Climate Variability and Water-Related Expenditure Behaviour: Evidence from Listed Agribusiness Firms in Nigeria

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ABSTRACT

This study examined the effect of climate variability on water-related expenditure behaviour among listed agribusiness firms in Nigeria. The study was motivated by increasing climatic uncertainty and limited empirical evidence regarding how climate-related pressures influence specific corporate expenditure categories. Specifically, it investigated the effects of rainfall variability and temperature variability on water-related energy expenditure, purchased water expenditure, and water treatment expenditure, while examining the moderating roles of firm size and leverage. An ex post facto research design was adopted, using panel data from 16 listed agribusiness firms in Nigeria covering the period 2015 to 2025, resulting in 176 firm-year observations. Climate data were obtained from the Nigerian Meteorological Agency (NiMet) and matched with the dominant operational locations of the sampled firms. The data were analysed using panel-data regression techniques, supported by appropriate model-selection criteria and diagnostic tests. The findings revealed that climate variability had no statistically significant effect on water-related energy expenditure, purchased water expenditure, or water treatment expenditure. However, firm size and leverage were found to moderate the relationship between climate variability and water-related expenditure, suggesting that organisational characteristics influence how climatic pressures translate into corporate financial outcomes. Based on these findings, the study recommended that listed agribusiness firms integrate rainfall and temperature variability indicators into water-infrastructure investment, operational planning, and resource-management decisions. Firms should also strengthen the identification, classification, and monitoring of water-related expenditure to improve climate resilience and support informed managerial decisions. The study contributes to knowledge by providing firm-level empirical evidence on the relationship between climate variability and water-related expenditure within Nigeria's agribusiness sector. Furthermore, it demonstrates the importance of examining disaggregated water-related expenditure categories in understanding corporate responses to climatic conditions. By distinguishing water-related energy, purchased water, and water treatment expenditure, the study provides a more detailed perspective on climate-related financial responses that may remain obscured when environmental expenditure is measured using aggregate indicators.

Keywords: *Rain-Fall Variability, Temperature Variability, Water Related Costs, Capital Expenditure Cost, Operational Expenditure Costs, Firm size and leverage, Agribusiness*

1. INTRODUCTION

Climate variability has increasingly become an important economic and operational concern for water-dependent agribusiness firms, particularly in developing economies such as Nigeria. Irregular rainfall patterns and rising temperatures create uncertainty in water availability, potentially increasing production costs and operational pressures (NiMet, 2023; IPCC, 2021). Water is essential to agribusiness activities, including processing, sanitation, cooling, cleaning, and quality control (Davis & Goldberg, 1957; OECD, 2018). Consequently, climatic fluctuations may influence corporate expenditure, resource allocation, and investment decisions beyond their immediate environmental implications (Seneviratne et al., 2021; FAO, 2024). Climate variability influences hydrological processes, groundwater recharge, surface water availability, and the reliability of water supply systems (Trenberth et al., 2014; IPCC, 2021). In Nigeria, variations in rainfall and temperature across ecological zones expose water-dependent businesses to operational and financial risks (Daramola et al., 2017; NiMet, 2023). Rising temperatures may increase evaporation and water demand, while irregular rainfall can undermine water replenishment and supply reliability. Therefore, these conditions may compel firms to incur additional expenditure on water sourcing, pumping, energy consumption, storage, treatment, and infrastructure maintenance (Mekonnen & Hoekstra, 2016; FAO, 2024). In another facet, this corroborates with Akpoyibo (2025c) view that the complexities of perfect workforce effectiveness in the public firms are often linked to certain climate.

Water-related expenditure encompasses the financial resources committed to obtaining, treating, storing, and utilising water for organisational activities. These costs include capital investments in boreholes and storage facilities, as well as operational expenses associated with energy consumption, purchased water, maintenance, and treatment chemicals (Burritt et al., 2011; Bebbington et al., 2014). Environmental Management Accounting emphasises identifying and measuring such costs, which are frequently embedded in conventional operating expenses, thereby limiting their visibility and managerial control (IFAC, 2005). However, the financial implications of climate variability may differ across firms depending on their infrastructure, operational capacity, and financial characteristics. In particular, firm size and leverage may influence their ability to absorb climatic pressures and finance adaptive investments (Uford, 2017). From an economic perspective, water constitutes an essential natural resource and production input whose availability and reliability are increasingly influenced by climatic conditions (Smith, 1776; Ricardo, 1817; IPCC, 2021). For agribusiness firms, these conditions may affect water-related capital expenditure (WCAPEX), water-related operational expenditure (WOPEX), water-related energy expenditure (ENEXP), purchased water expenditure (PWATER), and water treatment expenditure (TREAT). Nevertheless, existing researched have concentrated largely on agricultural productivity, water security, environmental sustainability, and corporate environmental disclosure, with comparatively limited attention to the disaggregated financial implications of climate variability for corporate water-related expenditure (OECD, 2021; He & Rosa, 2023).

This evidence gap is particularly relevant to listed agribusiness firms in Nigeria, where infrastructural limitations and geographical variations in climatic conditions may create different levels of exposure to water-related financial pressures. Furthermore, empirical evidence remains limited regarding whether firm size and financial leverage moderate the relationship between rainfall and temperature variability and corporate water-related expenditure. This study therefore examines the effects of rainfall and temperature variability

on water-related expenditure among listed agribusiness firms in Nigeria, while investigating the moderating roles of firm size and financial leverage. The study contributes to environmental management accounting and corporate climate resilience by providing firm-level evidence to support environmental cost identification, financial planning, resource allocation, and climate-responsive investment decisions.

Objectives of the Study

The main objective of this study is to examine the effect of climate variability on water-related expenditure behaviour among listed agribusiness firms in Nigeria.

Specifically, the study seeks to:

i. Determine the effect of rainfall variability and temperature variability on water-related energy expenditure among listed agribusiness firms in Nigeria;

ii. Evaluate the effect of rainfall variability and temperature variability on purchased water costs among listed agribusiness firms in Nigeria;

iii. Investigate the effect of rainfall variability and temperature variability on water treatment costs among listed agribusiness firms in Nigeria; and

iv. Examine the moderating effect of firm size and leverage on the relationship between climate variability and water-related expenditure behaviour among listed agribusiness firms in Nigeria.

2. **EMPIRICAL REVIEW**: Climate Variability and Water-Related Expenditure

Empirical studies published between 2024 and 2025 provide growing evidence that climate variability intensifies pressure on water resources, although its direct financial implications remain insufficiently investigated. Ray and Tikuye (2025), using hydrological modelling, established that changing precipitation patterns significantly alter river discharge regimes, affecting seasonal reliability and long-term water availability. Similarly, Lawal et al. (2025), applying rainfall and temperature indices and Sen's slope estimator to thirty years of Nigerian climate data, identified substantial rainfall variability and increasing dependence on groundwater resources. Although these studies demonstrate hydrological instability, neither quantified its associated economic or firm-level costs. At the corporate level, Olurin and Olaoye (2024), using panel regression data from five Nigerian agro-allied firms covering 2010-2022, found that rainfall and temperature had no statistically significant short-run effects on financial performance, whereas firm size and leverage were significant predictors. However, the study did not isolate water-related expenditure. Conversely, Iwe (2025), employing cointegration analysis, Vector Error Correction Models and Markov-switching techniques on Nigerian time-series data from 1960–2024, established that rainfall shocks significantly reduce agricultural output in the short run, suggesting indirect cost implications. Similarly, Eneji et al. (2024), using Autoregressive Distributed Lag and error-correction models for 2000-2023, found that rainfall variability significantly influences food price inflation, indicating climate-induced cost transmission through market prices. At the micro level, Olugbenga et al. (2025), analysing survey responses from 240 rice farmers through Seemingly Unrelated Regression, established that perceived climate variability significantly influences investment decisions concerning labour and fertiliser inputs, although reliance on perception-based climatic indicators limits objective measurement.

Further hydrological evidence reinforces the economic relevance of climate-induced water stress. Ogunbode et al. (2025), applying the Thornthwaite water balance model to meteorological data covering 1992–2022, identified declining water surplus and increasing drought intensity across Nigeria. Budnukaeku and Emmanuel (2024), using data spanning 1931-2020, associated extreme drought conditions with significant agricultural yield losses. Similarly, Abubakar et al. (2024) and Daniel and Ibrahim (2024) documented increasing rainfall variability across Nigeria's ecological zones. Earlier evidence from He and Rosa (2023), using global hydrological modelling, showed that rising temperatures intensify evapotranspiration and reduce soil moisture, while Utsev et al. (2023) established that irregular rainfall and increasing temperatures contribute to declining water availability in Nigeria. Although these studies demonstrate the physical and agricultural consequences of climate variability, they provide limited evidence of its direct corporate expenditure implications.

Relevant accounting evidence is provided by Okolie et al. (2022), who examined sustainability accounting and the financial performance of Nigerian manufacturing firms using an ex post facto design and six years of annual-report data. Their econometric findings revealed that social and environmental costs significantly influence financial performance, whereas corporate governance variables had no significant effect. This establishes the financial relevance of environmental expenditure but leaves unexplored the specific contribution of climate-induced water stress to corporate costs. Similarly, Adejuwon (2022), focusing on southwestern Nigeria, identified increasingly irregular rainfall patterns that undermine groundwater recharge and intensify water stress, even in areas with relatively high average rainfall. Nevertheless, the financial consequences for individual businesses were not investigated.

Studies conducted between 2017 and 2021 provide further evidence of the relationship between climate variability, water availability and expenditure. Kehinde et al. (2020), using survey and econometric methods, identified increased water-provision costs among Nigerian arable-crop farmers resulting from climate variability and dependence on alternative water sources. Although this represents direct empirical evidence of water-related costs, its focus on smallholder farmers limits its applicability to corporate agribusiness firms. Jibrin (2019), employing regression and correlation analysis, established that rainfall variability significantly affects water supply in Nigeria, although the investigation focused on public water infrastructure. At the international level, Zaveri et al. (2018), using firm-level survey data and econometric modelling across developing economies, found that unreliable water supply increases operating costs and reduces productivity. Adeniran et al. (2021) similarly established that Nigerian firms increasingly depend on private water infrastructure because of unreliable public supply, implying additional capital and operational expenditure. Evidence from the World Bank (2022) and Carbon Disclosure Project (2022) also indicates increasing water-related expenditure across water-intensive industries, although detailed accounting disaggregation remains limited. Complementary climatic studies by Daramola et al. (2017), Fuwape and Ogunjo (2018), Ogunjo et al. (2018), Muhammed et al. (2021), & Abdoulaye et al. (2021) documented significant rainfall and temperature variations, increasing drought frequency and irrigation demand, thereby establishing the physical basis of climate-induced water stress.

Earlier studies conducted before 2017 established the foundational relationship between climate variability and agricultural production. Oduyoye et al. (2014), using Error Correction Models on Nigerian data covering 1980-2012, identified a stable long-run relationship between climate variability and agricultural output. Similarly, Ayinde et al. (2010), Aye and Ater (2010), Davis & Sadiq (2010), & Apata (2001) demonstrated that rainfall and temperature

variability significantly influence agricultural production decisions and output. International evidence from Deschênes & Greenstone (2007), Hsiang (2010), Dell et al. (2014), Burke et al. (2015), and Carleton and Hsiang (2016), using panel regression, time-series and meta-analytical approaches, further established the adverse economic implications of climatic shocks across sectors and economies. However, these studies largely concentrated on agricultural output, profitability and economic growth without isolating corporate water-related expenditure.

Overall, the empirical literature establishes that rainfall and temperature variability affect water availability, agricultural productivity, operational conditions and economic performance. However, an important empirical gap persists concerning the direct transmission of climatic fluctuations into identifiable corporate water-related expenditure. Existing studies have either examined hydrological conditions without quantifying financial consequences, investigated agricultural costs without focusing on corporate firms, or assessed environmental expenditure without incorporating climatic variables. Furthermore, limited attention has been given to the potential moderating effects of firm size and leverage. The present study addresses these limitations by examining the effects of rainfall and temperature variability on water-related capital expenditure (WCAPEX), water-related operational expenditure (WOPEX), energy expenditure (ENEXP), purchased water expenditure (PWATER), and water treatment expenditure (TREAT), while investigating the moderating roles of firm size and leverage among listed agribusiness firms in Nigeria.

3. RESEARCH METHODOLOGY

This study adopted an ex post facto research design within a quantitative panel-data framework to examine the effect of climate variability on water-related expenditure among listed agribusiness firms in Nigeria. The design was appropriate because the study relied on historical climatic and corporate financial data that could not be manipulated by the researcher (Kerlinger & Lee, 2000; Charles & Uford, 2023). The population consisted of 20 companies listed on the Nigerian Exchange Group, from which the sample was purposively selected based on the availability of audited annual reports, relevant financial information, identifiable operational locations, and consistent observations. The study covered 16 listed agribusiness firms, comprising 176 firm-year observations from 2015 to 2025. Four firms were excluded because they did not meet the selection criteria. Climate data were obtained from the Nigerian Meteorological Agency (NiMet) and matched with the primary operational locations of the sampled firms to account for geographical differences in climatic conditions.

The dependent variables were water-related capital expenditure (WCAPEX), water-related operating expenditure (WOPEX), water-related energy expenditure (ENEXP), purchased water expenditure (PWATER), and water treatment expenditure (TREAT). The independent variables were rainfall variability, measured using the coefficient of variation of annual rainfall, and temperature variability, measured as the difference between annual maximum and minimum temperatures. Firm size, measured as the natural logarithm of total assets, and leverage, measured as total liabilities divided by total assets, served as moderating variables. Expenditure data were extracted from audited annual reports using the Accounting-Based Water Expenditure Identification Framework (ABWEIF), developed with reference to Environmental Management Accounting and Material Flow Cost Accounting principles. Only identifiable and verifiable water-related expenditure items were included. The natural logarithm of each expenditure variable was used in the regression models.

The study specified separate panel regression models for each expenditure category. The baseline models examined the effects of rainfall and temperature variability on water-related expenditure, while the moderation models incorporated firm size, leverage, and their interaction terms with the climatic variables. The models were estimated using Pooled Ordinary Least Squares, Fixed Effects, and Random Effects techniques. The Breusch-Pagan Lagrange Multiplier test was used to guide the choice between pooled and random-effects estimation, while the Hausman specification test informed the selection between fixed and random effects. Diagnostic tests included the Variance Inflation Factor for multicollinearity and tests for heteroscedasticity and serial correlation. Robust standard errors were applied where necessary to improve the reliability of statistical inference (Baltagi, 2021; Wooldridge, 2020).

Decision Rule

The hypotheses are tested at the 5% level of significance. The null hypothesis is rejected where the probability value (p-value) is less than or equal to 0.05 ($p \leq 0.05$). Where the p-value exceeds 0.05 ($p > 0.05$), the null hypothesis is not rejected. The direction of a statistically significant coefficient is determined by its sign, while the magnitude provides an indication of the extent of the estimated relationship.For the moderation models, the statistical significance and sign of the interaction coefficients are used to determine whether firm size and leverage significantly modify the relationship between climate variability and the respective water-related expenditure outcomes.

Model I: Water-Related Capital Expenditure

$$LWCAPEX_{it} = \beta_0 + \beta_1 RVI_{it} + \beta_2 TVI_{it} + \beta_3 FSIZE_{it} + \beta_4 LEV_{it} + \varepsilon_{it}$$

Model II: Water-Related Operational Expenditure

$$LWOPEX_{it} = \beta_0 + \beta_1 RVI_{it} + \beta_2 TVI_{it} + \beta_3 FSIZE_{it} + \beta_4 LEV_{it} + \varepsilon_{it}$$

Model III: Water-Related Energy Expenditure

$$LENEXP_{it} = \beta_0 + \beta_1 RVI_{it} + \beta_2 TVI_{it} + \beta_3 FSIZE_{it} + \beta_4 LEV_{it} + \varepsilon_{it}$$

Model IV: Purchased Water Costs

$$LPWATER_{it} = \beta_0 + \beta_1 RVI_{it} + \beta_2 TVI_{it} + \beta_3 FSIZE_{it} + \beta_4 LEV_{it} + \varepsilon_{it}$$

Model V: Water Treatment Costs

$$LTREAT_{it} = \beta_0 + \beta_1 RVI_{it} + \beta_2 TVI_{it} + \beta_3 FSIZE_{it} + \beta_4 LEV_{it} + \varepsilon_{it}$$

LWCAPEX = Natural logarithm of water-related capital expenditure

LWOPEX= Natural logarithm of water-related operating expenditure

LENEXP = Natural logarithm of water-related energy expenditure

LPWATER = Natural logarithm of purchased water expenditure

LTREAT = Natural logarithm of water treatment expenditure

RVI= Rainfall Variability Index

TVI= Temperature Variability Index

FSIZE= Firm size, measured as the natural logarithm of total assets

LEV= Leverage, measured as total liabilities divided by total assets

β_0= Constant term

β_1–β_8= Regression coefficients

ε_{it}= Error term

i= Individual firms

t= Study year

The specified models examine the effects of climate variability on each category of water-related expenditure and assess the moderating roles of firm size and leverage.

4. RESULTS AND DISCUSSION

This section presents the empirical results and discusses the findings in relation to the study objectives, hypotheses, theoretical framework, and relevant literature. The analysis uses panel data from 16 sampled firms covering 2015–2025, comprising 176 firm-year observations. The presentation begins with the observed climatic conditions and derived climate variability indicators. Annual rainfall, maximum temperature, minimum temperature, the Rainfall Variability Index (RVI), and the Temperature Variability Index (TVI) are examined to establish climatic patterns during the study period. Subsequently, descriptive statistics, diagnostic tests, and econometric analyses are presented and discussed.

Table 1: Descriptive Statistics of the Regression Variables

Variable	Observations	Mean	Median	Minimum	Maximum	Std. Dev.
LWCAPEX	176	15.2313	15.2225	10.8627	18.4813	1.2784
LWOPEX	176	16.3277	16.5126	12.7248	19.3821	1.4376
LENEXP	176	14.1904	14.2874	10.1197	17.9507	1.5249
LPWATER	176	13.2942	13.3712	9.2034	17.0344	1.5032
LTREAT	176	14.4392	14.4902	10.3020	18.1330	1.4737
RVI	176	0.8974	0.8777	0.5741	2.0394	0.2062
TVI	176	8.8694	8.3202	7.5750	16.0753	1.7557
FSIZE	176	18.4973	18.6447	14.3693	21.3111	1.3539
LEV	176	0.6283	0.6168	0.0517	1.1751	0.1936

Source: Researcher's computation from the study dataset, 2026.

Table 1 presents the descriptive statistics of the study variables, covering 176 firm-year observations. The mean values were 15.2313 for LWCAPEX, 16.3277 for LWOPEX, 14.1904 for LENEXP, 13.2942 for LPWATER, and 14.4392 for LTREAT. Their standard deviations were 1.2784, 1.4376, 1.5249, 1.5032, and 1.4737, respectively. Regarding climate variables, RVI averaged 0.8974, while TVI averaged 8.8694. Firm size recorded a mean of 18.4973, whereas leverage averaged 0.6283. The observed variations indicate differences in climatic conditions and expenditure patterns, supporting further correlation and panel regression analyses.

Table 2: Correlation Matrix of the Regression Variables

Variable	LWCAPEX	LWOPEX	LENEXP	LPWATER	LTREAT	RVI	TVI	FSIZE	LEV
LWCAPEX	1.000	0.727	0.779	0.784	0.802	−0.324	−0.300	0.824	0.239

LWOPEX	0.727	1.000	0.730	0.748	0.784	−0.325	−0.266	0.892	0.092
LENEXP	0.779	0.730	1.000	0.994	0.956	−0.116	−0.135	0.833	0.346
LPWATER	0.784	0.748	0.994	1.000	0.971	−0.123	−0.142	0.847	0.337
LTREAT	0.802	0.784	0.956	0.971	1.000	−0.148	−0.159	0.871	0.305
RVI	−0.324	−0.325	−0.116	−0.123	−0.148	1.000	0.713	−0.302	−0.075
TVI	−0.300	−0.266	−0.135	−0.142	−0.159	0.713	1.000	−0.206	0.098
FSIZE	0.824	0.892	0.833	0.847	0.871	−0.302	−0.206	1.000	0.153
LEV	0.239	0.092	0.346	0.337	0.305	−0.075	0.098	0.153	1.000

Source: Researcher's computation from the study dataset, 2026.

Table 2 reveals positive correlations among expenditure variables, particularly LENEXP and LPWATER (r = 0.994), LPWATER and LTREAT (r = 0.971), and LENEXP and LTREAT (r = 0.956). RVI and TVI correlate negatively with all expenditure measures, while their mutual correlation is positive (r = 0.713). Firm size correlates positively with expenditure variables (0.824–0.892), whereas leverage shows weaker positive associations (0.092–0.346). These results indicate preliminary relationships among the variables. However, high correlations among dependent variables do not independently establish multicollinearity within separate regression equations. Therefore, diagnostic tests will assess multicollinearity among explanatory variables before regression estimation.

Table 3: Variance Inflation Factor (VIF) of the Explanatory Variables

Variable	**VIF**
RVI	2.215
TVI	2.138
FSIZE	1.122
LEV	1.076

Source: Researcher's computation from the study dataset, (2026).

The Variance Inflation Factor (VIF) results presented indicate values ranging from 1.076 for LEV to 2.215 for RVI. Specifically, RVI and TVI recorded the highest VIF values of 2.215 and 2.138, respectively, while FSIZE and LEV recorded considerably lower values of 1.122 and 1.076. These values suggest that multicollinearity among the explanatory variables is relatively low. Consequently, the regression estimates are unlikely to be adversely affected by excessive linear relationships among the predictors. Therefore, all four explanatory variables are retained for subsequent panel regression estimation, as the VIF diagnostic provides no evidence of serious multicollinearity that could compromise the reliability of the empirical results.

Table 4: Panel Model Selection Results

Dependent Variable	**LM Statistic**	**LM p-value**	**Hausman Statistic**	**Hausman p-value**	**Preferred Model**

LWCAPEX	474.1169	<0.001	5.2699	0.2607	Random Effects
LWOPEX	378.3045	<0.001	0.7842	0.9405	Random Effects
LENEXP	98.6325	<0.001	44.8397	<0.001	Fixed Effects
LPWATER	108.1255	<0.001	37.0027	<0.001	Fixed Effects
LTREAT	192.7799	<0.001	28.9256	<0.001	Fixed Effects

Source: Researcher's computation from the study dataset, (2026).

The Breusch–Pagan Lagrange Multiplier (LM) test results are statistically significant across all five models ($p < 0.001$), indicating the presence of significant panel effects and suggesting that panel estimation is more appropriate than pooled OLS. The Hausman specification test was subsequently conducted to determine the appropriate estimator between fixed and random effects. The results support the Random Effects model for LWCAPEX and LWOPEX, with p-values of 0.2607 and 0.9405, respectively. Conversely, the Hausman tests for LENEXP, LPWATER, and LTREAT are statistically significant ($p < 0.001$), favouring the Fixed Effects specification. Accordingly, Table 4.6 presents the diagnostic results and selected estimators.

Table 5: Panel Regression Diagnostic Tests

Dependent Variable	**Selected Model**	**Wooldridge Statistic**	**p-value**	**Heteroskedasticity Statistic**	**p-value**	**Pesaran CD Statistic**	**p-value**	**Serial Correlation**	**Heteroskedasticity**	**Cross-sectional Dependence**
LWCAPEX	Random Effects	115.8072	<0.001	34.3038	<0.001	9.9872	<0.001	Present	Present	Present
LWOPEX	Random Effects	61.8969	<0.001	19.9680	<0.001	1.7958	0.0725	Present	Present	Not detected
LENEXP	Fixed Effects	26.7283	<0.001	15.2604	0.0042	4.1710	<0.001	Present	Present	Present
LPWATER	Fixed Effects	22.2557	<0.001	16.7026	0.0022	4.0236	<0.001	Present	Present	Present
LTREAT	Fixed Effects	20.4956	<0.001	25.3580	<0.001	4.7710	<0.001	Present	Present	Present

Source: Researcher's computation from the study dataset, (2026).

The diagnostic results reveal statistically significant serial correlation and heteroscedasticity across all five models, as evidenced by the Wooldridge and heteroscedasticity tests. Furthermore, Pesaran's cross-sectional dependence test is statistically significant for LWCAPEX, LENEXP, LPWATER, and LTREAT, indicating interdependence across firms in these models. However, the result for LWOPEX is statistically insignificant at the 5% level (p = 0.0725), suggesting no sufficient evidence of cross-sectional dependence.

These findings indicate that conventional panel standard errors may produce unreliable statistical inferences because of the identified diagnostic problems. Consequently, Driscoll–Kraay robust standard errors are employed to improve the reliability of the regression estimates and statistical inference. This approach provides a basis for evaluating the estimated coefficients and their statistical significance while accounting for the identified dependence and error-variance concerns. Accordingly, the subsequent regression results are interpreted using robust standard errors to assess the relationships between climate variability and water-related expenditure.

Table 6: Regression Results on Climate Variability and Corporate Water-Related Expenditure

Dependent Variable	Model	Variable	Coefficient	Robust SE	Test Statistic	p-value	95% CI Lower	95% CI Upper	Sig.
LWCAPEX	Random Effects	RVI	0.2565	0.1285	1.996	0.0475	0.0046	0.5084	**
		TVI	-0.0255	0.0099	-2.583	0.0106	-0.0449	-0.0062	**
		FSIZE	0.9409	0.0350	26.912	<0.001	0.8724	1.0095	***
		LEV	-0.1103	0.0880	-1.253	0.2120	-0.2828	0.0623	
LWOPEX	Random Effects	RVI	0.0556	0.3159	0.176	0.8604	-0.5635	0.6748	
		TVI	-0.1341	0.0372	-3.602	<0.001	-0.2071	-0.0612	***
		FSIZE	0.9171	0.0253	36.305	<0.001	0.8676	0.9666	***
		LEV	0.0152	0.1363	0.111	0.9114	-0.2520	0.2824	
LENEXP	Fixed Effects	RVI	0.4416	0.4239	1.042	0.2991	-0.3892	1.2723	
		TVI	-0.0996	0.0511	-1.947	0.0533	-0.1998	0.0006	*
		FSIZE	1.0041	0.0559	17.965	<0.001	0.8945	1.1136	***
		LEV	0.4153	0.3153	1.317	0.1898	-0.2028	1.0334	

LPWATER	Fixed Effects	RVI	0.3454	0.4250	0.813	0.4176	-0.4877	1.1785	
		TVI	-0.0810	0.0528	-1.535	0.1268	-0.1845	0.0224	
		FSIZE	1.0122	0.0508	19.928	<0.001	0.9126	1.1117	***
		LEV	0.3488	0.2627	1.328	0.1862	-0.1661	0.8638	
LTREAT	Fixed Effects	RVI	-0.0831	0.5447	-0.153	0.8790	-1.1506	0.9845	
		TVI	-0.0545	0.0501	-1.089	0.2780	-0.1527	0.0436	
		FSIZE	1.0430	0.0432	24.129	<0.001	0.9583	1.1277	***
		LEV	0.0755	0.1453	0.519	0.6042	-0.2093	0.3603	

Notes: *RVI = Rainfall Variability Index; TVI = Temperature Variability Index; FSIZE = Firm Size; LEV = Leverage. LWCAPEX = Log of Water-related Capital Expenditure; LWOPEX = Log of Water-related Operating Expenditure; LENEXP = Log of Energy Expenditure; LPWATER = Log of Purchased Water Expenditure; LTREAT = Log of Water Treatment Expenditure. Driscoll–Kraay robust standard errors are reported. ***, ** and * denote statistical significance at 1%, 5% and 10%, respectively.* ***Source:*** *Researcher's computation from the study dataset, (2026).*

The results are presented below according to the expenditure outcomes specified in the study objectives.

Effect of Climate Variability on Water-Related Capital Expenditure

For water-related capital expenditure (LWCAPEX), rainfall variability has a positive and statistically significant coefficient ($\beta = 0.2565$, $p = 0.0475$), while temperature variability has a negative and statistically significant coefficient ($\beta = -0.0255$, $p = 0.0106$). Firm size is also positive and highly significant ($\beta = 0.9409$, $p < 0.001$), whereas leverage is not statistically significant ($\beta = -0.1103$, $p = 0.2120$).

Effect of Climate Variability on Water-Related Operating Expenditure

For water-related operating expenditure (LWOPEX), rainfall variability has a positive but statistically insignificant coefficient ($\beta = 0.0556$, $p = 0.8604$). In contrast, temperature variability has a negative and statistically significant coefficient ($\beta = -0.1341$, $p < 0.001$). Firm size remains positive and highly significant ($\beta = 0.9171$, $p < 0.001$), while leverage is statistically insignificant ($\beta = 0.0152$, $p = 0.9114$).

Effect of Climate Variability on Energy Expenditure

For energy expenditure (LENEXP), rainfall variability has a positive but insignificant coefficient ($\beta = 0.4416$, $p = 0.2991$). Temperature variability has a negative coefficient ($\beta = -0.0996$, $p = 0.0533$), which is marginally significant at the 10% level. Firm size is positive

and highly significant (β = 1.0041, p < 0.001), while leverage is insignificant (β = 0.4153, p = 0.1898).

Effect of Climate Variability on Purchased Water Expenditure

For purchased water expenditure (LPWATER), neither rainfall variability (β = 0.3454, p = 0.4176) nor temperature variability (β = −0.0810, p = 0.1268) is statistically significant. Firm size is positive and highly significant (β = 1.0122, p < 0.001), whereas leverage is not significant (β = 0.3488, p = 0.1862).

Effect of Climate Variability on Water Treatment Expenditure

For water treatment expenditure (LTREAT), rainfall variability (β = −0.0831, p = 0.8790) and temperature variability (β = −0.0545, p = 0.2780) are both statistically insignificant. Firm size remains positive and highly significant (β = 1.0430, p < 0.001), while leverage is statistically insignificant (β = 0.0755, p = 0.6042).

Overall, the regression estimates show that the statistically significant direct effects of climate variability are concentrated in water-related capital expenditure and operating expenditure, with rainfall variability positively associated with capital expenditure and temperature variability negatively associated with both capital and operating expenditure. The remaining expenditure outcomes do not exhibit statistically significant direct climate effects at the conventional 5% level. These results provide the empirical basis for the subsequent assessment of the moderating effects of firm characteristics.

Moderating Effect of Firm Characteristics

To examine whether firm characteristics alter the relationship between climate variability and expenditure outcomes, interaction terms between rainfall variability (RVI) and temperature variability (TVI) and the two firm characteristics—firm size (FSIZE) and leverage (LEV)—were introduced into the respective panel models. The results are presented in Table 7. The models retain the selected estimation techniques identified earlier, with Driscoll–Kraay robust standard errors used for statistical inference.

Table 7: Moderating Effect of Firm Characteristics on the Relationship between ClimateVariability and Expenditure Outcomes

Dependent Variable	Interaction Term	Coefficient	Robust SE	t-statistic	p-value	Direction	Moderation Decision
LWCAPEX	RVI × FSIZE	0.3139	0.0540	5.816	<0.001	Positive	Significant positive moderation
	TVI × FSIZE	−0.0223	0.0066	−3.371	0.0009	Negative	Significant negative moderation
	RVI × LEV	−2.5687	0.7990	−3.215	0.0016	Negative	Significant negative moderation
	TVI × LEV	0.2554	0.0811	3.149	0.0019	Positive	Significant positive moderation
LWOPEX	RVI × FSIZE	−0.0274	0.0371	−0.739	0.4608	Negative	Not significant

	TVI × FSIZE	−0.0042	0.0112	−0.376	0.7073	Negative	Not significant
	RVI × LEV	−1.1059	0.5468	−2.022	0.0447	Negative	Significant negative moderation
	TVI × LEV	−0.1452	0.0918	−1.581	0.1158	Negative	Not significant
LENEXP	RVI × FSIZE	−0.2115	0.1449	−1.459	0.1465	Negative	Not significant
	TVI × FSIZE	0.0533	0.0341	1.562	0.1203	Positive	Not significant
	RVI × LEV	−3.9560	0.7381	−5.360	<0.001	Negative	Significant negative moderation
	TVI × LEV	−0.0910	0.1147	−0.793	0.4288	Negative	Not significant
LPWATER	RVI × FSIZE	−0.2217	0.1450	−1.528	0.1285	Negative	Not significant
	TVI × FSIZE	0.0523	0.0329	1.590	0.1138	Positive	Not significant
	RVI × LEV	−3.7164	0.6632	−5.604	<0.001	Negative	Significant negative moderation
	TVI × LEV	−0.1157	0.1117	−1.035	0.3022	Negative	Not significant
LTREAT	RVI × FSIZE	−0.3382	0.1500	−2.254	0.0256	Negative	Significant negative moderation
	TVI × FSIZE	0.0589	0.0314	1.878	0.0623	Positive	Weak positive moderation
	RVI × LEV	−2.0750	0.6735	−3.081	0.0024	Negative	Significant negative moderation
	TVI × LEV	−0.2164	0.1534	−1.410	0.1604	Negative	Not significant

Source: Researcher's computation from the study dataset, 2026.

The moderation results reveal outcome-specific effects of firm size and leverage on the relationship between climate variability and water-related expenditure. For LWCAPEX, all four interaction terms are statistically significant. RVI×FSIZE is positive (β = 0.3139), while TVI×FSIZE is negative (β = −0.0223). Similarly, RVI×LEV is negative (β = −2.5687), whereas TVI×LEV is positive (β = 0.2554), all at 1% significance. For LWOPEX, only RVI×LEV is significantly negative (β = −1.1059, $p < 0.05$). For LENEXP and LPWATER, RVI×LEV is also significantly negative, with coefficients of −3.9560 and −3.7164, respectively ($p < 0.01$). Regarding LTREAT, RVI×FSIZE is negative and significant, while TVI×FSIZE is positive and significant at 10%. RVI×LEV is also significantly negative. The remaining interactions are insignificant. Joint Wald tests reject the null hypothesis across all five outcomes ($p < 0.001$), confirming that firm size and leverage collectively moderate the relationship between climate variability and expenditure outcomes.

Summary of Hypotheses Testing

The joint hypothesis tests are presented in Table 8 For hypotheses H01–H05, the joint significance of RVI and TVI is assessed for each expenditure outcome. Hypothesis H06 assesses the joint moderating role of firm size and leverage across the expenditure equations.

Table 8: Summary of Hypothesis Testing

Hypothesis	Analytical Focus	Selected Model	Wald Statistic	df	p	Decision
H_{01}	Joint effect of RVI and TVI on LWCAPEX	Random Effects	7.558	2	.023	Reject H_{01}
H_{02}	Joint effect of RVI and TVI on LWOPEX	Random Effects	13.078	2	.001	Reject H_{02}
H_{03}	Joint effect of RVI and TVI on LENEXP	Fixed Effects	4.286	2	.117	Do not reject H_{03}
H_{04}	Joint effect of RVI and TVI on LPWATER	Fixed Effects	2.678	2	.262	Do not reject H_{04}
H_{05}	Joint effect of RVI and TVI on LTREAT	Fixed Effects	1.371	2	.504	Do not reject H_{05}
H_{06}	Moderating effect of firm size and leverage on climate variability–expenditure relationships	Five expenditure equations	—	—	—	Reject H_{06}

Note. RVI = Rainfall Variability Index; TVI = Temperature Variability Index; LWCAPEX = water-related capital expenditure; LWOPEX = water-related operating expenditure; LENEXP = energy expenditure; LPWATER = purchased water expenditure; LTREAT = water treatment expenditure; df = degrees of freedom. Decisions for H_{01}–H_{05} are based on the joint tests of the restrictions RVI = 0 and TVI = 0 at the 5% significance level. For H_{06}, significant joint moderation was identified in all five expenditure equations.
Source: Researcher's computation from the study dataset, 2026.

The results show that the joint effects of rainfall and temperature variability are statistically significant for LWCAPEX (p = 0.0229) and LWOPEX (p = 0.0014). The corresponding joint tests for LENEXP (p = 0.1173), LPWATER (p = 0.2621), and LTREAT (p = 0.5039) are not statistically significant at the 5% level. Accordingly, H01 and H02 are rejected, while H03, H04, and H05 are not rejected.

For H06, the moderation analysis provides evidence of significant joint moderation in all five expenditure equations. The null hypothesis of no significant moderation is therefore rejected at the 5% level.

Discussion of Findings

The discussion of findings is organised according to the specific objectives of the study. Emphasis is placed on the direction, magnitude, and statistical significance of the estimated coefficients, their consistency with the study's theoretical foundations, and their alignment with the empirical evidence reviewed.

Objective One: Effect of Climate Variability on Water-Related Capital Expenditure

The first objective examined the effect of climate variability on water-related capital expenditure among listed Nigerian agribusiness firms. Table 6 indicates that rainfall variability positively affects expenditure ($\beta = 0.2565$, $p = 0.0475$), while temperature variability has a significant negative effect ($\beta = -0.0255$, $p = 0.0106$). The joint Wald test confirms significance ($p = 0.0229$); therefore, H01 is rejected.The positive rainfall coefficient suggests that climatic

uncertainty encourages investment in water infrastructure, storage, irrigation, and treatment facilities. This aligns with Nigerian studies linking rainfall variability to water availability and agricultural conditions (Akinbile et al., 2020; Akpalu et al., 2016; Omokaro, 2025). Conversely, temperature variability may encourage alternative operational adaptations rather than water-related capital investment.These findings support the integrated NRBV-DCT-EMA framework, highlighting water as a strategic resource, organisational adaptation capabilities, and expenditure identification. Firm size positively influences capital expenditure ($\beta = 0.9409$, $p < 0.001$), whereas leverage is insignificant ($p = 0.212$). Overall, climate variability significantly influences expenditure, but its effects differ by climatic indicator.

Objective Two: Effect of Climate Variability on Water-Related Operational Expenditure

The second objective examined the effect of rainfall and temperature variability on water-related operational expenditure (WOPEX) among listed Nigerian agribusiness firms. The significant joint Wald test in Table 8 confirms the relevance of climate variability, although individual estimates indicate that temperature variability primarily drives this relationship.Rainfall variability has no significant effect, contradicting the *a priori* expectation and Kehinde et al. (2020), who found increased water-provision costs among Nigerian arable crop farmers. This difference may reflect the greater infrastructure, technical capacity, and resource-management systems of listed firms, enabling them to absorb rainfall fluctuations without significant operational expenditure changes. The finding aligns with Olurin and Olaoye (2024), who reported no significant short-run relationship between climatic conditions and Nigerian agro-allied firm outcomes.Temperature variability exhibits a significant negative association with WOPEX, contrary to expectations. This suggests lower reported recurring water expenditure during periods of greater temperature fluctuation, rather than necessarily reduced water-management needs. From the Dynamic Capability Theory perspective, firms may reconfigure operations and improve efficiency under environmental uncertainty, although the specific mechanisms remain unidentified.Overall, climate variability influences WOPEX selectively, demonstrating that corporate expenditure responses differ across climatic indicators and expenditure categories.

Objective Three: Effect of Climate Variability on Energy Expenditure

The third objective examined the effects of rainfall and temperature variability on energy expenditure among listed Nigerian agribusiness firms. Table 6 shows that neither variable significantly affects energy expenditure. Similarly, the joint Wald test is insignificant (Wald = 4.286, p = .1173); therefore, H03 is not rejected.The insignificant rainfall coefficient contradicts the expectation that rainfall instability influences energy costs through irrigation, pumping, and drainage. Likewise, the negative temperature coefficient provides insufficient evidence of a systematic relationship with energy expenditure. Thus, climate variability does not significantly explain energy expenditure within the sampled firms.Although climate adaptation literature suggests that climatic stress may increase energy requirements for cooling, irrigation, and pumping, energy expenditure may depend more heavily on technological, operational, and production-related factors. Any climate influence may be indirect or insufficiently pronounced to produce statistically significant results. However, the estimated model does not identify specific mechanisms.The findings align with Dynamic Capability Theory (DCT), suggesting that firms may manage environmental pressures through operational adjustments without substantial expenditure changes. They also support the Natural Resource-Based View (NRBV), indicating that environmental pressures affect expenditure categories differently.Among the controls, firm size positively and significantly influences energy expenditure, whereas leverage is positive but insignificant. Overall, climate variability does not significantly explain energy expenditure.

Objective Four: Effect of Climate Variability on Purchased Water Expenditure

Objective Four examined the effects of rainfall and temperature variability on purchased water expenditure among listed Nigerian agribusiness firms. Table 6 shows that neither variable significantly affects expenditure. Similarly, the joint Wald test is insignificant (Wald = 2.678, p = .2621); therefore, H04 is not rejected.The insignificant rainfall coefficient contradicts the expectation that rainfall instability increases reliance on purchased water. Although temperature variability has a negative coefficient, its effect is statistically insignificant. Thus, climate variability does not explain changes in purchased water expenditure within the sampled firms.This finding suggests that established water infrastructure and internal management systems may reduce firms' dependence on external water procurement during climatic fluctuations. However, the regression model does not establish this mechanism.The results align with the integrated NRBV-DCT-EMA framework. The NRBV perspective suggests that water-resource uncertainty does not necessarily increase external water acquisition, while DCT emphasises adaptation through existing capabilities and resource reconfiguration. EMA further enables distinctions between purchased water expenditure and other water-related costs.Regarding controls, firm size positively and significantly influences purchased water expenditure, whereas leverage is positive but insignificant. Overall, purchased water expenditure appears more strongly associated with factors beyond the climate variability indicators examined, distinguishing it from expenditure categories demonstrating significant climatic effects.

5. CONCLUDING REMARKS

Conclusion

This study concludes that climate variability influences water-related expenditure among listed Nigerian agribusiness firms selectively, depending on the climatic indicator and expenditure category. Significant effects were observed for water-related capital and operational expenditure, whereas energy, purchased water, and water treatment expenditure showed no significant climate effects.The findings further establish that firm characteristics shape expenditure responses. Firm size and leverage significantly moderate relationships involving rainfall variability, demonstrating that organisational resources and financial structures influence how climatic pressures translate into expenditure decisions.Theoretically, the findings support the integrated Natural Resource-Based View (NRBV), Dynamic Capability Theory (DCT), and Environmental Management Accounting (EMA) framework. Climate variability creates environmental pressures, organisational capabilities shape adaptive responses, and EMA enables these responses to be identified through specific expenditure categories.Overall, climate variability produces targeted rather than uniform expenditure adjustments. Disaggregating water-related expenditure therefore provides clearer insights into corporate adaptation and the financial implications of climate-related risks within Nigeria's agribusiness sector.

Recommendations

Based on the empirical findings, the following recommendations are made:

i. Management should integrate rainfall variability into infrastructure planning, particularly for water storage, irrigation, drainage, and related investments.

ii. Management should incorporate temperature variability into operational planning and budgeting to improve resource allocation and expenditure management.

iii. Firms should adopt disaggregated Environmental Management Accounting practices, maintaining separate records for water-related capital, operational, energy, purchased-water, and treatment expenditures.

iv. Management should consider firm size and leverage when designing climate-response strategies, ensuring that water-expenditure decisions reflect differences in organisational capacity and financial structure.

Contributions to Knowledge

The study makes three major contributions to knowledge:

i. It provides firm-level evidence that climate variability selectively affects water-related capital and operational expenditure, rather than all expenditure categories uniformly, among listed Nigerian agribusiness firms.

ii. It extends the integrated NRBV-DCT-EMA framework to corporate water expenditure, demonstrating how environmental pressures, organisational capabilities, firm size, and leverage shape climate-related expenditure responses.

iii. It develops the Accounting-Based Water Expenditure Identification Framework (ABWEIF) to identify and disaggregate water-related capital, operational, energy, purchased-water, and treatment expenditure from corporate financial disclosures, improving expenditure visibility and empirical analysis.

REFERENCES

Abdoulaye, A. O., Lu, H., Zhu, Y., & Hamoud, Y. A. (2021). Future irrigation water requirements of the main crops cultivated in the Niger River Basin. *Atmosphere, 12*(4), Article 439.

Abubakar, A., Lawal, U., & Mohammed, A. J. (2024). Long-term rainfall variability and drought characteristics in Kaduna State, Nigeria. *Journal of Water and Climate Change, 15*(3), 1243–1258.

Abubakar, M. L., Abdussalam, A. F., Ahmed, M. S., & Wada, A. I. (2024). Spatiotemporal variability of rainfall and drought characterisation in Kaduna, Nigeria. Discover Environment, 2(1), Article 72.

Adejuwon, J. O. (2022). Rainfall variability and water stress in south-western Nigeria. Climate Research, 82(3), 45–60.

Adeniran, A., Daniell, K. A., & Pittock, J. (2021). Industrial water use and adaptation strategies in Nigeria. Journal of Environmental Management, 287, Article 112124.

African Development Bank. (2024, July 1). Nigeria-Urban Water Reform & Akure Water Supply and Sanitation Project (P-NG-E00-014).

Akpoyibo, G. (2025c). Merit-based recruitment and employee effectiveness: a bivariate study of selected southern Nigerian public enterprises. *Futur Bus J* 11, 264 (2025). https://doi.org/10.1186/s43093-025-00687-4.

Auffhammer, M., Hsiang, S. M., Schlenker, W., & Sobel, A. (2013). Using weather data and climate model output in economic analyses of climate change. Review of Environmental Economics and Policy, 7(2), 181–198.

Baltagi, B. H. (2021). Econometric analysis of panel data (6th ed.). Springer.

Bebbington, J., Larrinaga, C., & O'Dwyer, B. (2014). Accounting and accountability for the environment. Accounting, Auditing & Accountability Journal, 27(2), 395–413.

Budnukaeku, A. C., & Emmanuel, O. S. (2024). Historical analysis of climate variability and agricultural production in Nigeria (1931–2020). Climate Change, 10, Article e8cc1039.

Burke, M., Hsiang, S. M., & Miguel, E. (2015). Global non-linear effect of temperature on economic production. Nature, 527, 235–239.

Burritt, R. L., Schaltegger, S., &Zvezdov, D. (2011). Carbon management accounting: Explaining practice in leading German companies. Australian Accounting Review, 21(1), 80–98.

Carbon Disclosure Project. (2022). Water security and corporate adaptation: Global report.

Carleton, T. A., & Hsiang, S. M. (2016). Social and economic impacts of climate. Science, 353(6304), Article aad9837.

Charles, I. I., & Uford, I. C. (2023). Comparative analysis and evaluation of business and financial performance of Amazon. Com: A three-year period critical review of exceptional success. *European Journal of Business, Economics and Accountancy*, *11*(2), 69-92.

Daramola, M. T., Eresanya, E. O., &Erhabor, S. C. (2017). Analysis of rainfall and temperature over climatic zones in Nigeria. Journal of Geography, Environment and Earth Science International, 11(2), 1–14.

Davis, J. H., & Goldberg, R. A. (1957). A concept of agribusiness. Division of Research, Graduate School of Business Administration, Harvard University.

Dell, M., Jones, B. F., & Olken, B. A. (2014). What do we learn from the weather? The new climate-economy literature. Journal of Economic Literature, 52(3), 740–798.

Deschênes, O., & Greenstone, M. (2007). The economic impacts of climate change: Evidence from agricultural output and random fluctuations in weather. American Economic Review, 97(1), 354–385.

Eneji, M. A., Nnamdi, V. N., Manomi, J. N., & Iliya, E. (2024). Climate change and food price inflation in Nigeria. Journal of Economics and Financial Issues, 7(2), 1–15.

Food and Agriculture Organization of the United Nations. (2015). Climate change and food security: Risks and responses. FAO.

Food and Agriculture Organization of the United Nations. (2019). The state of the world's water resources for food and agriculture. FAO.

Food and Agriculture Organization of the United Nations. (2020). The state of food and agriculture 2020: Overcoming water challenges in agriculture.

He, L., & Rosa, L. (2023). Solutions to agricultural green water scarcity under climate change. PNAS Nexus, 2(4), Article pgad117.

Intergovernmental Panel on Climate Change. (2021). Climate change 2021: The physical science basis. Cambridge University Press.

International Federation of Accountants. (2005). International guidance document: Environmental management accounting. IFAC.

Iwe, E. P. (2025). Impact of climate variability on agricultural productivity and economic growth in Nigeria. African Journal of Agricultural and Resource Economics, 20(3), 1–18.

Kehinde, A. L., Alao, O. T., Busari, A. O., &Oyaromade, R. (2020). Climate change, cost of providing water and livelihood diversification by arable crop farmers in Nigeria. Nigerian Journal of Agricultural Economics, 10(1), 92–108.

Lawal, A., Adigun, H. A., Aliyu, M., Wakawa, D. T., & Damana, U. M. (2025). Impacts of climate variability on sustainable agricultural water management in Yauri, Northwestern Nigeria. FUDMA Journal of Sciences, 9(12), 1–15.

Mekonnen, M. M., & Hoekstra, A. Y. (2016). Four billion people facing severe water scarcity. Science Advances, 2(2), Article e1500323.

Muhammed, I., Abdussalam, A. F., & Isa, Z. (2021). Spatial and temporal variability of 40 years temperature and precipitation in the savanna region, Nigeria. FUDMA Journal of Sciences.

Nigerian Meteorological Agency. (2023). Annual climate review bulletin. NiMet.

Oduyoye-Ejumedia, A. O., Ogunro, T. T., &Aderinto, E. R. (2014). Climate variability: Implications for agricultural produce in Nigeria. In Proceedings of the Climate Variability Conference (pp. 1–12).

Ogunbode, T. O., Esan, V. I., Aweda, F. O., & Oyebamiji, V. O. (2025). Assessing the impact of climate variability on water balance and availability in Iwo, Osun State, Nigeria (1992–2022). Discover Environment, 3, Article 266.

Okolie, A. O., Ewiwile, S., & Okunola, O. A. (2022). Sustainability accounting and performance of manufacturing industry in Nigeria. International Journal for Research in Business, Management and Accounting, 8(3), 1–11.

Olugbenga, Y. E., Bamire, A. S., Kehinde, A. D., Ojo, T. O., &Ogundeji, A. A. (2025). Impact of perceptions of climate variability on investment decisions among smallholder rice farmers in Nigeria. Environmental and Sustainability Indicators, 27, Article 100721.

Olurin, E. O., & Olaoye, B. J. (2024). Climate variability and financial performance of agro-allied firms in Nigeria. Nigerian Journal of Accounting and Finance, 16(2), 186–203.

Organisation for Economic Co-operation and Development. (2018). Water management in OECD countries: Policy challenges. OECD.

Ray, R. L., &Tikuye, B. G. (2025). Effect of climate change on surface water resources. In R. L. Ray and B. G. Tikuye (Eds.), Limnology: Surface and groundwater ecosystems. IntechOpen.

Ricardo, D. (1817). On the principles of political economy and taxation. John Murray.

Schaltegger, S., & Burritt, R. L. (2018). Business cases and corporate engagement with sustainability: Differentiating ethical motivations. Journal of Business Ethics, 147(2), 241–259.

Seneviratne, S. I., Zhang, X., Adnan, M., Badi, W., Dereczynski, C., Di Luca, A., Ghosh, S., Iskandar, I., Kossin, J., Lewis, S., Otto, F., Pinto, I., Satoh, M., Vicente-Serrano, S. M., Wehner, M., & Zhou, B. (2021). Weather and climate extreme events in a changing climate. In V. Masson-Delmotte et al. (Eds.), Climate change 2021: The physical science basis (pp. 1513–1766). Cambridge University Press.

Smith, A. (1776). An inquiry into the nature and causes of the wealth of nations. W. Strahan & T. Cadell.

Trenberth, K. E., Dai, A., Van Der Schrier, G., Jones, P. D., Barichivich, J., Briffa, K. R., & Sheffield, J. (2014). Global warming and changes in drought. Nature Climate Change, 4(1), 17–22.

Uford, I. C. (2017). *Customer and Employee-based Brand Equity Driving United Bank for Africa's Market Performance*. University of the Witwatersrand, Johannesburg (South Africa).

UNESCO World Water Assessment Programme. (2023). The United Nations world water development report 2023: Partnerships and cooperation for water. UNESCO.

UNESCO. (2020). World water development report 2020: Water and climate change. United Nations Educational, Scientific and Cultural Organization.

Utsev, T., Imoni, S., Akande, E. O., Tiza, M. T., &Onuzulike, C. (2023). The effects of climate change on water resources and their effect on food security in Nigeria. International Journal of Energy Applications and Technologies, 10(2), 58–73.

Wooldridge, J. M. (2019). Introductory econometrics: A modern approach (7th ed.). Cengage Learning.

World Bank. (2013). Turn down the heat: Climate extremes, regional impacts, and the case for resilience. World Bank.

World Bank. (2022). Water stress and industrial adaptation in developing economies. World Bank Publications.

Zaveri, E., Russ, J., & Damania, R. (2018). The drivers and impacts of water infrastructure reliability: A global analysis of manufacturing firms. Science of the Total Environment, 644, 1220–1230.