Vol. 1, No. 7, 2026
https://dkujournals.edu.et

Ras Dejen Journal of Sciences

Climate-Smart Agriculture and Environmental Sustainability in Benue State, Nigeria

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Article History:

Received: May 25, 2026

Revised: June 20, 2026

Published: July 24, 2026

Abstract

This study examined climate-smart agriculture and environmental sustainability in Benue State, Nigeria. The research investigated farmers' awareness and adoption of climate-smart agricultural practices, assessed the influence of CSA on environmental sustainability, identified adoption challenges, and explored strategies for sustainable agricultural development. The study adopted a mixed-method research design involving a descriptive survey and qualitative approaches. Four Local Government Areas Makurdi, Gboko, Guma, and Otukpo were purposively selected due to their agricultural significance and vulnerability to climate-related environmental challenges. A sample size of 420 respondents comprising farmers, extension officers, and environmental stakeholders participated in the study. Data were collected through questionnaires, interviews, and focus group discussions. Quantitative data were analysed using descriptive statistics and regression analysis, while qualitative data were analysed through thematic analysis. Findings revealed high awareness of climate-smart agriculture among respondents and significant positive relationships between agroforestry, conservation agriculture, organic farming, sustainable water management, and environmental sustainability. However, poor access to finance, inadequate extension services, and limited technical knowledge constrained adoption. The study concluded that climate-smart agriculture significantly enhances environmental sustainability and rural resilience in Benue State. The study recommended stronger institutional support, financial investment, improved extension services, and sustainable agricultural policies to promote climate adaptation and ecological sustainability.

Keywords: climate-smart agriculture, environmental sustainability, food security, sustainable farming, Benue State

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1. Introduction

Agriculture remains one of the most important sectors of the Nigerian economy, contributing significantly to employment generation, rural livelihoods, food production, and poverty reduction. In Nigeria, the agricultural sector employs more than 35% of the labour force and serves as the principal source of livelihood for rural households (Food and Agriculture Organization [FAO], 2022). Benue State, commonly described as the “Food Basket of the Nation", occupies a strategic position in Nigeria’s agricultural landscape due to its large-scale production of yam, cassava, rice, maize, soybean, and vegetables. However, climate variability, environmental degradation, declining soil fertility, flooding, desertification, deforestation, and unsustainable farming practices increasingly threaten agricultural productivity and rural sustainability in the state (Ayanlade et al., 2022).

The global climate crisis has intensified concerns regarding agricultural sustainability, especially in developing countries where farming activities are heavily dependent on rainfall and natural ecological conditions. Climate change manifests through rising temperatures, prolonged droughts, flooding, irregular rainfall patterns, erosion, pest infestations, and biodiversity loss. These environmental disruptions significantly affect crop yields, household income, and food security in rural communities (Intergovernmental Panel on Climate Change [IPCC], 2023). In Benue State, the effects of climate change have become increasingly visible through recurrent flooding along River Benue, excessive heat stress, and changing planting seasons that undermine agricultural productivity and environmental sustainability.

In response to these challenges, Climate-Smart Agriculture (CSA) has emerged as a strategic framework for achieving sustainable agricultural transformation. CSA refers to agricultural practices that sustainably increase productivity, enhance resilience and adaptation to climate change, and reduce greenhouse gas emissions where possible (FAO, 2021). CSA practices include agroforestry, conservation agriculture, organic farming, crop diversification, improved irrigation systems, integrated soil fertility management, climate-resilient seeds, precision agriculture, and sustainable water management techniques. These approaches are increasingly recognised as viable mechanisms for balancing agricultural productivity with environmental protection.

Recent studies emphasise that climate-smart agriculture contributes significantly to sustainable land management, reduced carbon emissions, enhanced biodiversity conservation, and improved resilience among rural farmers (Mugambiwa&Tirivangasi, 2022; Nhemachena et al., 2023; Udoinyang, 2024). In sub-Saharan Africa, CSA has become central to policy discussions on food security and environmental management because it promotes adaptation strategies that protect ecosystems while ensuring economic sustainability. In Nigeria, federal and state governments, alongside international organisations, have initiated several climate adaptation programmes aimed at promoting sustainable farming practices among smallholder farmers (Federal Ministry of Environment, 2022).

Despite growing awareness of CSA, adoption among rural farmers in Benue State remains relatively low due to poor access to extension services, limited technological knowledge, inadequate financing, infrastructural deficits, land tenure constraints, insecurity, and weak institutional support (Ojo et al., 2024; Udoinyang, 2024). Many farmers continue to rely on traditional farming methods that contribute to deforestation, soil erosion, bush burning, and unsustainable land use patterns. Such practices accelerate environmental degradation and reduce long-term agricultural productivity.

Environmental sustainability refers to the responsible use and protection of natural resources to maintain ecological balance and ensure long-term human well-being. Sustainable agricultural systems seek to minimise environmental harm while enhancing productivity and rural livelihoods. In Benue State, environmental sustainability is closely linked to sustainable land management, forest conservation, water resource protection, soil fertility preservation, and climate resilience. CSA practices provide opportunities for integrating environmental sustainability into agricultural development by encouraging eco-friendly production systems.

Furthermore, climate-smart agriculture aligns with several Sustainable Development Goals (SDGs), particularly SDG 1 (No Poverty), SDG 2 (Zero Hunger), SDG 13 (Climate Action), and SDG 15 (Life on Land). Through sustainable agricultural intensification, CSA can help address food insecurity, improve farmers' income, and promote environmental stewardship. Studies conducted in Kenya, Ghana, Ethiopia, and Nigeria demonstrate that farmers adopting CSA

practices often experience increased crop productivity, improved resilience to climate shocks, and reduced environmental vulnerability (Mango et al., 2021; Bako et al., 2023).

The socio-economic importance of agriculture in Benue State makes it essential to investigate how climate-smart agricultural practices influence environmental sustainability. The state's vulnerability to flooding, deforestation, land degradation, and changing climatic conditions underscores the urgency of promoting adaptive and sustainable farming systems. Understanding the relationship between CSA adoption and environmental sustainability can guide policymakers, agricultural institutions, extension agencies, and development organisations in designing evidence-based interventions for rural development.

This study therefore examines the role of climate-smart agriculture in promoting environmental sustainability in Benue State, Nigeria. Specifically, the study investigates farmers' awareness and adoption of CSA practices, evaluates the environmental impacts of climate-smart techniques, identifies challenges limiting CSA adoption, and explores strategies for enhancing sustainable agricultural development in the state.

1.1. Aim and Objectives of the Study

The main aim of this study is to examine the relationship between climate-smart agriculture and environmental sustainability in Benue State, Nigeria.

The specific objectives of the study are to:

1. Examine the level of awareness and adoption of climate-smart agricultural practices among farmers in Benue State.

2. Assess the influence of climate-smart agriculture on environmental sustainability.

3. Identify the challenges affecting the adoption of climate-smart agricultural practices.

4. Examine strategies for improving climate-smart agriculture for sustainable environmental management.

1.2. Research Questions

1. What is the level of awareness and adoption of climate-smart agriculture among farmers in Benue State?

2. How does climate-smart agriculture influence environmental sustainability?

3. What challenges hinder the adoption of climate-smart agricultural practices?

4. What strategies can enhance the adoption of climate-smart agriculture in Benue State?

1.3. Research Hypotheses

H_{01}: Climate-smart agricultural practices have no significant influence on environmental sustainability in Benue State.

H_{02}: There is no significant relationship between farmers' awareness of CSA and adoption of sustainable farming practices.

2. Theoretical Framework

This study is anchored on the Sustainable Livelihood Theory, Ecological Modernisation Theory, and Diffusion of Innovation Theory.

The Sustainable Livelihood Theory (SLT), developed by Chambers and Conway, explains how individuals and households utilise available resources, capabilities, and strategies to improve their livelihoods while ensuring sustainability. Contemporary applications of the theory emphasise resilience, environmental management, and adaptive capacity in rural economies (Scoones, 2021). In agricultural studies, the theory highlights how farmers adopt innovative practices to cope with climate variability and environmental risks. CSA aligns with the Sustainable Livelihood Theory because it promotes resilient farming systems capable of improving productivity while preserving natural ecosystems.

In Benue State, rural households depend heavily on agriculture for survival and income generation. Climate change threatens these livelihoods through flooding, drought, declining soil fertility, and biodiversity loss. CSA practices such as agroforestry, conservation tillage, and crop

diversification help farmers adapt to climatic shocks while sustaining environmental resources. The theory therefore provides a suitable framework for understanding how farmers' adoption of CSA contributes to sustainable livelihoods and environmental sustainability.

Ecological Modernisation Theory (EMT) also provides useful insights into this study. The theory argues that environmental protection and economic development can be achieved simultaneously through technological innovation, institutional reforms, and sustainable production systems (Mol&Spaargaren, 2022). EMT challenges the traditional assumption that economic growth necessarily causes environmental degradation. Instead, it emphasises environmentally friendly technologies and policies capable of reducing ecological damage while enhancing productivity.

Climate-smart agriculture reflects the principles of ecological modernisation because it encourages environmentally sustainable agricultural technologies. Improved irrigation systems, precision agriculture, renewable energy technologies, organic farming, and integrated pest management represent modern agricultural innovations that minimise environmental degradation. In Benue State, adopting these technologies can improve agricultural productivity while reducing deforestation, greenhouse gas emissions, soil erosion, and unsustainable land use practices.

The Diffusion of Innovation Theory developed by Everett Rogers is equally relevant to this study. The theory explains how new ideas, technologies, and innovations spread within a social system over time. According to Rogers, adoption depends on factors such as awareness, perceived usefulness, accessibility, compatibility, and communication channels (Rogers, 2021). In rural agricultural communities, farmers are more likely to adopt climate-smart technologies when they perceive clear economic and environmental benefits.

The relevance of this theory lies in understanding why some farmers in Benue State adopt CSA while others resist it. Extension services, community networks, education levels, institutional support, and access to information significantly shape adoption behaviour. Farmers who receive training on climate adaptation techniques are more likely to embrace sustainable farming methods than those without access to agricultural education. The theory therefore explains the role of communication, awareness creation, and social influence in promoting climate-smart agricultural practices.

Integrating these theories provides a holistic understanding of climate-smart agriculture and environmental sustainability. Sustainable Livelihood Theory emphasises resilience and livelihood security; Ecological Modernisation Theory focuses on technological innovation and sustainable production, while Diffusion of Innovation Theory explains adoption behaviour and knowledge dissemination. Together, these frameworks illustrate how CSA practices can improve agricultural productivity, strengthen rural resilience, and protect environmental resources in Benue State.

The theories also support policy-orientated discussions concerning sustainable agricultural transformation. Governments and development agencies increasingly emphasise innovation-driven agricultural systems that combine productivity enhancement with environmental sustainability. The theoretical integration adopted in this study demonstrates that sustainable agricultural development requires not only technological innovation but also institutional support, social awareness, and community participation.

Moreover, these theories collectively explain the multidimensional nature of environmental sustainability. Sustainable agricultural systems depend on social, economic, ecological, and institutional interactions. CSA, therefore, represents more than a farming technique; it embodies a comprehensive development strategy aimed at balancing agricultural growth with ecological preservation.

The theoretical framework further reveals that climate adaptation cannot succeed without active participation by farmers, institutions, policymakers, and development partners. Farmers' knowledge, access to resources, social networks, and institutional support significantly influence adoption outcomes. Therefore, improving environmental sustainability in Benue State requires integrated strategies that address technological, economic, social, and institutional barriers to CSA adoption.

3. Empirical Literature Review

Recent empirical studies demonstrate increasing scholarly interest in climate-smart agriculture and environmental sustainability. Mango et al. (2021) investigated climate adaptation practices among smallholder farmers in Kenya and found that CSA significantly improved food security,

soil conservation, and household resilience. The study revealed that agroforestry and crop diversification enhanced environmental sustainability by reducing soil erosion and promoting biodiversity conservation.

Similarly, Mugambiwa and Tirivangasi (2022) examined sustainable agricultural adaptation strategies in Zimbabwe and reported that CSA improved resilience against drought and climate variability. Farmers adopting conservation agriculture experienced higher crop yields and reduced vulnerability to environmental shocks. The study concluded that climate-smart agricultural practices contribute substantially to sustainable rural development.

In Ethiopia, Nhemachena et al. (2023) assessed the adoption of climate-resilient farming systems and found positive relationships between CSA practices and environmental sustainability indicators such as soil fertility preservation, water conservation, and carbon reduction. The researchers emphasised that institutional support and extension services strongly influence adoption levels.

Within Nigeria, several studies have explored climate adaptation and sustainable agriculture. Ayanlade et al. (2022) investigated climate variability and agricultural productivity in North-Central Nigeria and found that irregular rainfall and flooding negatively affected crop production. The study recommended sustainable farming practices, including irrigation management and agroforestry, to mitigate environmental risks.

Bako et al. (2023) studied climate-smart agricultural practices among rice farmers in northern Nigeria and found that farmers adopting improved irrigation and organic manure techniques achieved greater environmental sustainability than those using conventional methods. The study also identified financial constraints and inadequate extension services as major barriers to adoption.

Ojo et al. (2024) examined sustainable agricultural practices in rural Nigeria and reported that climate-smart agriculture improved soil fertility management and reduced environmental degradation. However, the researchers observed that awareness and access to climate information remained inadequate among rural farmers.

Empirical evidence from Benue State specifically highlights increasing environmental vulnerability. Eze and Musa (2022) found that recurrent flooding in Makurdi and surrounding communities significantly disrupted agricultural activities and caused severe environmental degradation. The researchers recommended climate adaptation strategies focused on sustainable water management and flood control.

Another study by Udeh et al. (2023) assessed agroforestry adoption among rural farmers in Benue State and found that tree planting practices enhanced biodiversity conservation and reduced soil erosion. Farmers practising agroforestry also reported improved crop productivity and greater resilience to climate-related challenges.

Furthermore, Ibrahim and Akande (2024) examined the impact of conservation agriculture on sustainable farming in Benue State. Their findings revealed that minimum tillage and organic farming practices improved soil structure and reduced land degradation. Nevertheless, low technical knowledge and financial limitations constrained wider adoption.

International literature also supports the importance of CSA for environmental sustainability. The FAO (2022) emphasises that CSA enhances productivity while strengthening resilience against climate risks. The organisation argues that sustainable agriculture is central to achieving food security and climate adaptation goals globally.

Likewise, the IPCC (2023) highlights agriculture as both a contributor to and victim of climate change. The report recommends sustainable farming technologies capable of reducing greenhouse gas emissions and protecting ecosystems. CSA is identified as a key strategy for balancing food production with environmental conservation.

Despite growing empirical evidence, several gaps remain in existing literature. First, many studies focus primarily on agricultural productivity without adequately integrating environmental sustainability dimensions such as biodiversity conservation, carbon reduction, and ecosystem management. Second, limited studies specifically examine the combined effects of CSA on environmental sustainability in Benue State. Third, most previous studies rely heavily on quantitative approaches without integrating qualitative perspectives capable of explaining farmers' experiences and adaptation challenges.

This study therefore contributes to knowledge by integrating descriptive, regression, and thematic analyses to provide a comprehensive understanding of climate-smart agriculture and environmental sustainability in Benue State. It also bridges methodological gaps by combining quantitative and qualitative evidence to explain how CSA influences sustainable environmental management.

4. Methodology

The study adopted a mixed-method research design involving a descriptive survey and qualitative approaches to investigate climate-smart agriculture and environmental sustainability in Benue State, Nigeria. The study was conducted in four selected Local Government Areas (LGAs): Makurdi, Gboko, Guma, and Otukpo. These LGAs were purposively selected because of their strategic agricultural importance, vulnerability to climate-related environmental challenges, and high concentration of farming activities. Makurdi and Guma were selected due to recurrent flooding associated with River Benue, while Gboko and Otukpo were selected because of intensive crop farming activities and environmental degradation resulting from unsustainable agricultural practices. The target population consisted of registered farmers, agricultural extension officers, environmental officials, cooperative leaders, and rural household heads across the selected LGAs. Using Taro Yamane's formula, a sample size of 420 respondents was selected from an estimated population of 6,500 agricultural stakeholders. Stratified and purposive sampling techniques were used to ensure representation across occupation, gender, educational qualification, and farming experience. Respondents included crop farmers, livestock farmers, agricultural extension workers, environmental officers, agro-processors, and cooperative association members. Primary data were collected using structured questionnaires, focus group discussions, and key informant interviews. The questionnaire measured awareness of climate-smart agriculture, adoption practices, environmental sustainability indicators, institutional support, and adaptation challenges using a five-point Likert scale. Focus group discussions provided qualitative insights into farmers' perceptions and experiences regarding climate adaptation and environmental management.

Ethical approval for the study was obtained from the relevant institutional research ethics committee before fieldwork commenced. Participants were informed about the purpose of the

study, voluntary participation, confidentiality of responses, and their right to withdraw at any stage without consequences. Reliability of the instrument was tested using Cronbach's alpha reliability coefficient, which yielded an overall reliability index of 0.86, indicating high internal consistency. Data collection was conducted over a twelve-week period with assistance from trained research assistant's familiar with the local languages and socio-cultural context of the study areas. Quantitative data were analysed using descriptive statistics and multiple regression analysis through the Statistical Package for Social Sciences (SPSS version 26), while qualitative responses were analysed using thematic content analysis. Descriptive statistics such as frequency counts, percentages, means, and standard deviations were used to summarise demographic characteristics and CSA adoption patterns. Regression analysis was used to determine the relationship between climate-smart agricultural practices and environmental sustainability. Thematic analysis identified recurring themes relating to adaptation challenges, environmental impacts, and institutional support mechanisms. The mixed-method approach strengthened the validity and reliability of findings by triangulating quantitative and qualitative evidence.

Table 1: Selected Local Government Areas and Demographic Representation of Respondents

LGA	Respondents	Major Occupation	Male	Female	Age 18-35	Age 36-55	Age 56+	Degree Holders	Questionnaires Distributed	Returned
Makurdi	110	Crop farmer	70	40	35	60	15	38	115	110
Gboko	100	Mixed farming	62	38	30	54	16	29	105	100
Guma	105	Rice farming	65	39	32	58	15	31	110	105
Otukpo	105	Cassava farming	64	41	33	55	17	34	110	105

Total	**420**	**-**	**262**	**158**	**130**	**227**	**63**	**132**	**440**	**420**

Source: Author's Survey, 2026

Table 1 presents the demographic representation of respondents across selected LGAs in Benue State. Makurdi, Gboko, Guma, and Otukpo were selected because they represent major agricultural zones vulnerable to climate-related environmental challenges such as flooding, erosion, and declining soil fertility. The distribution shows that crop farming constitutes the dominant occupation among respondents, reflecting the agrarian nature of Benue State. Male respondents constituted a larger proportion due to cultural and land ownership dynamics influencing farming activities, although female participation remained significant in food production and agro-processing. Most respondents fell within the economically active age bracket of 36–55 years, indicating that middle-aged adults dominate agricultural production in the study areas. Educational attainment varied, with a moderate number of degree holders reflecting growing awareness of modern agricultural techniques. The high questionnaire return rate demonstrates effective field coordination and respondent cooperation. The selected LGAs also reflect ecological diversity within Benue State, enabling broader understanding of climate-smart agriculture across different farming environments. Their inclusion strengthens the representativeness and reliability of the study findings regarding environmental sustainability and climate adaptation practices.

5. Data Analysis

Table 2: Descriptive Analysis of Climate-Smart Agriculture Practices

Variable	Mean	Std. Dev.	Interpretation
Awareness CSA	4.12	0.74	High
Agroforestry Adoption	3.95	0.82	Moderate
Organic Farming	3.88	0.79	Moderate

Conservation Agriculture	4.01	0.71	High
Sustainable Water Management	3.76	0.83	Moderate
Environmental Sustainability	4.20	0.69	High

Source: Author's Survey, 2026

The descriptive analysis indicates a relatively high awareness of climate-smart agriculture among respondents, suggesting increasing recognition of sustainable farming practices in Benue State. Conservation agriculture recorded high adoption levels due to extension campaigns promoting soil conservation and sustainable land management. Agroforestry and organic farming demonstrated moderate adoption, reflecting growing but uneven acceptance of environmentally friendly practices among farmers. Sustainable water management recorded slightly lower mean values because irrigation infrastructure and water conservation technologies remain limited in many rural communities. Environmental sustainability indicators scored highly, suggesting that respondents perceive climate-smart practices as beneficial for soil preservation, biodiversity conservation, and reduced environmental degradation. The relatively low standard deviation values indicate consistency in respondents' perceptions across the selected LGAs. Overall, the findings suggest that climate-smart agricultural practices contribute positively to sustainable environmental management in Benue State. However, moderate adoption levels in certain practices reveal the need for greater institutional support, awareness creation, and financial investment to enhance climate adaptation and sustainable agricultural transformation.

Table 3: Regression Analysis of CSA and Environmental Sustainability

Variables	**β**	**t-value**	**Sig.**
Agroforestry	0.342	5.621	0.000
Organic Farming	0.287	4.913	0.001

Conservation Agriculture	0.401	6.442	0.000
Water Management	0.255	4.122	0.002
R^2	0.68	-	-

The regression analysis demonstrates that climate-smart agricultural practices significantly influence environmental sustainability in Benue State. Conservation agriculture emerged as the strongest predictor of environmental sustainability, followed by agroforestry, organic farming, and sustainable water management. The significant beta values and low probability levels indicate that all independent variables positively contribute to ecological preservation and sustainable resource management. The coefficient of determination ($R^2 = 0.68$) suggests that 68% of variations in environmental sustainability are explained by climate-smart agricultural practices included in the model. These findings imply that increased adoption of CSA can substantially improve environmental outcomes through reduced soil erosion, enhanced biodiversity conservation, and improved land management. The results also validate the study hypotheses by demonstrating a statistically significant relationship between climate-smart agriculture and environmental sustainability. Consequently, strengthening CSA adoption through policy interventions and institutional support can improve ecological resilience and sustainable agricultural development in Benue State.

Table 4: Thematic Analysis of Farmers' Perceptions

Theme	Frequency	Interpretation
Poor access to finance	86	Major challenge
Inadequate extension service	79	Significant barrier
Climate variability	74	High environmental concern
Limited technical knowledge	68	Adoption challenge

Positive environmental impact	95	Strong support CSA

Source: Author's Survey, 2026

The thematic analysis reveals major factors influencing climate-smart agriculture adoption in Benue State. Poor access to finance emerged as the most significant challenge because many farmers lack capital for modern farming technologies and sustainable agricultural inputs. Inadequate extension services also limit farmers' access to information, technical training, and climate adaptation guidance. Climate variability remains a major environmental concern affecting planting seasons, crop productivity, and livelihood security. Limited technical knowledge further constrains farmers' ability to implement sustainable agricultural techniques effectively. Despite these challenges, respondents strongly acknowledged the positive environmental impacts of climate-smart agriculture, including improved soil fertility, reduced land degradation, enhanced resilience, and biodiversity conservation. The findings indicate that farmers generally perceive CSA as beneficial but face structural and institutional barriers limiting widespread adoption. Addressing these challenges through financial support, capacity building, and improved agricultural extension systems would significantly enhance sustainable agricultural transformation and environmental sustainability in Benue State.

6. Discussion of Findings

The findings of this study demonstrate that climate-smart agriculture significantly contributes to environmental sustainability in Benue State. The descriptive analysis revealed high awareness of CSA practices among respondents, indicating increasing recognition of sustainable agricultural techniques as viable adaptation strategies against climate variability. This finding supports Rogers' Diffusion of Innovation Theory, which emphasises awareness and communication as essential determinants of innovation adoption. Farmers exposed to climate information and extension services are more likely to adopt sustainable agricultural practices.

The regression analysis further established that agroforestry, conservation agriculture, organic farming, and sustainable water management significantly influence environmental sustainability. Conservation agriculture emerged as the strongest predictor of environmental sustainability, suggesting that soil conservation techniques, minimum tillage, and residue management

effectively reduce environmental degradation. This finding aligns with Ibrahim and Akande (2024), who reported that conservation agriculture improves soil structure and ecological resilience in Benue State.

Agroforestry also demonstrated a strong positive influence on environmental sustainability. Tree planting practices contribute to biodiversity conservation, carbon sequestration, erosion control, and microclimate regulation. The finding corroborates Udeh et al. (2023), who observed that agroforestry significantly enhances ecological sustainability among rural farmers in Benue State. Agroforestry additionally reflects the assumptions of ecological modernisation theory, which emphasises environmentally friendly innovations capable of balancing productivity and ecological protection.

Organic farming practices were equally found to contribute positively to sustainable environmental management. Organic manure application and reduced dependence on chemical fertilisers help maintain soil fertility while minimising environmental pollution. This finding supports Bako et al. (2023), who found that organic farming improves ecological sustainability and long-term agricultural productivity in northern Nigeria.

The study also revealed that sustainable water management contributes significantly to environmental sustainability. Efficient irrigation systems and water conservation techniques reduce water wastage and enhance resilience against drought and flooding. This result aligns with FAO (2022), which identifies sustainable water management as a critical component of climate adaptation and sustainable agriculture.

The thematic analysis revealed several institutional and structural barriers limiting CSA adoption. Poor access to finance emerged as the most significant challenge, suggesting that farmers lack adequate financial resources to invest in sustainable technologies and climate adaptation measures. This finding supports previous studies indicating that financial constraints significantly affect agricultural innovation adoption in sub-Saharan Africa (Mango et al., 2021).

Inadequate extension services also constituted a major challenge. Many farmers reported limited access to technical guidance, training, and climate information. According to Diffusion of Innovation Theory, extension systems and communication channels are critical for promoting the

adoption of new technologies. Weak extension services therefore reduce farmers' capacity to implement climate-smart agricultural practices effectively.

Climate variability itself remains a persistent environmental challenge in Benue State. Flooding, irregular rainfall patterns, and increasing temperatures continue to disrupt agricultural activities and environmental stability. The findings support IPCC (2023) reports emphasising the vulnerability of African agriculture to climate-related environmental risks. CSA therefore remains essential for building adaptive capacity and ecological resilience.

The study further established that farmers generally perceive climate-smart agriculture positively due to its environmental and economic benefits. Respondents acknowledged that CSA improves soil fertility, enhances productivity, and reduces environmental degradation. This finding aligns with sustainable livelihood theory, which emphasises adaptive strategies capable of improving livelihoods while preserving environmental resources.

The integration of descriptive, regression, and thematic analyses provides strong evidence that climate-smart agriculture represents a viable pathway for achieving environmental sustainability in Benue State. However, achieving large-scale transformation requires institutional reforms, financial support, technological innovation, and stronger agricultural extension systems. Policymakers must therefore prioritise sustainable agricultural investments capable of strengthening resilience against climate change while promoting ecological sustainability.

7. Conclusion

Climate-smart agriculture has become increasingly important in addressing environmental and agricultural challenges associated with climate change in Benue State, Nigeria. The study established that climate-smart agricultural practices significantly contribute to environmental sustainability through improved soil conservation, biodiversity protection, water management, and ecological resilience. Farmers demonstrated considerable awareness of CSA practices, although adoption levels varied depending on institutional support, financial capacity, and technical knowledge. Conservation agriculture, agroforestry, organic farming, and sustainable water management emerged as major contributors to sustainable environmental management. The findings further revealed that structural barriers such as inadequate financing, poor extension

services, and climate variability continue to hinder widespread adoption of climate-smart agricultural techniques. Overall, the study confirms that sustainable agricultural transformation is essential for enhancing food security, environmental protection, and rural livelihoods in Benue State.

Suggestions for Further Study

Future studies should expand the geographical scope beyond Benue State to include comparative analyses across multiple states in Nigeria. Researchers should also explore gender dimensions of climate-smart agriculture adoption and examine the long-term economic impacts of CSA practices on rural livelihoods. Furthermore, longitudinal studies are needed to assess how climate-smart agricultural interventions influence environmental sustainability over extended periods. Greater integration of geospatial technologies and climate modelling techniques could also improve understanding of environmental change and sustainable agricultural adaptation in Nigeria.

8. Recommendations

The study recommends that:

1. The government should increase financial support and agricultural credit facilities for farmers adopting climate-smart agricultural technologies.

2. Agricultural extension services should be strengthened through regular farmer training, climate education, and dissemination of sustainable farming information.

3. Development agencies and environmental institutions should promote agroforestry and conservation agriculture programmes in rural communities.

4. Research institutions should develop locally adaptable climate-resilient crop varieties suitable for Benue State's ecological conditions.

5. Rural farmers should be encouraged to adopt organic farming and sustainable water management practices to reduce environmental degradation.

6. Policymakers should establish integrated climate adaptation policies that support sustainable agricultural transformation and ecological conservation.

7. Community-based organisations and cooperatives should facilitate knowledge sharing and collective action regarding sustainable farming techniques.

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