International Journal of Innovative Agriculture & Biology Research 14(1):56-74, Jan.-Mar., 2026

 www.seahipublications.org ISSN: 2354- 2934

doi:10.5281/zenodo.18936625

Assessing Adoption, Yield Response, and Livelihood Outcomes among Smallholder Farmers in Obi LGA, Nasarawa State, Nigeria

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ABSTRACT

This study assessed the adoption of climate-smart agriculture (CSA), its yield response, and livelihood outcomes among smallholder maize farmers in Obi Local Government Area of Nasarawa State, Nigeria. The research employed a mixed-methods approach combining quantitative and qualitative techniques to examine the determinants and impacts of CSA adoption. Primary data were collected from 240 maize-farming households through structured questionnaires, key-informant interviews, and focus group discussions. A logit regression model was used to analyse the determinants of CSA adoption, while a production-function model evaluated the effects of adoption on maize yield. Descriptive analysis was further applied to assess livelihood outcomes among adopters and non-adopters. The results revealed that education, farm size, access to extension services, availability of agricultural credit, and access to climate-information services significantly influenced farmers' decisions to adopt CSA practices. The most commonly adopted practices included improved climate-resilient maize varieties, intercropping, mulching, minimum tillage, and fertiliser micro-dosing. Findings also indicated that CSA adopters achieved higher maize yields and experienced improved food security, greater income stability, and enhanced adaptive capacity compared to non-adopters. However, adoption intensity varied due to institutional and financial constraints. The study concludes that strengthening extension systems, improving access to climate information, and expanding inclusive agricultural finance are critical for scaling CSA adoption and enhancing the resilience of smallholder farming systems.

Keywords: Climate-smart agriculture, smallholder farmers, maize productivity, climate adaptation, livelihood outcomes.

1. INTRODUCTION

1.1 Climate Change, Agriculture, and Food Security in Sub-Saharan Africa

Climate change has emerged as one of the most profound structural challenges confronting agricultural systems in sub-Saharan Africa (SSA), where food production remains predominantly rain-fed and dominated by smallholder farmers (Bello et al., 2025; Olusola et al., 2025; Abubakar et al. 2025). Rising temperatures, increasing rainfall variability, prolonged dry spells, and a growing frequency of extreme weather events are fundamentally altering production conditions, amplifying yield instability and undermining rural livelihoods (IPCC, 2023; FAO, 2024). These climatic pressures interact with long-standing structural constraints—such as limited access to finance, weak extension systems, degraded soils, and underdeveloped markets—rendering smallholder farmers particularly vulnerable to climate-induced shocks (Musa et al.., 2025; Ibrahim et al., 2025; Magaji & Aliyu, 2007).

Empirical evidence from across SSA shows that climate variability has already reduced crop yields and increased production volatility, with disproportionately adverse effects on poorer households that lack risk-management instruments (Dillon & Barrett, 2022; van Ittersum & van Bussel, 2023). Projected climate scenarios suggest that, without effective adaptation, yield losses for major cereals could intensify by mid-century, exacerbating food insecurity and poverty (Fischer et al., 2023). These dynamics underscore the centrality of agriculture in climate adaptation debates and the urgency of strategies that enhance both productivity and resilience.

Maize occupies a particularly critical position within African food systems. As one of the most widely cultivated cereals in SSA, maize is central to food availability, household income generation, and national food security. However, maize is also highly sensitive to climate stress, especially rainfall timing and temperature extremes during flowering and grain-filling stages. Recent studies document significant climate-related yield losses in maize across West, East, and Southern Africa, with smallholders bearing the greatest burden (Abate et al., 2023; Amare et al., 2024).

In Nigeria, these challenges are especially pronounced. Nigeria is the largest maize producer in SSA, and maize plays a dual role as both a staple food and a commercial crop supplying urban markets and livestock feed industries (FMARD, 2022; World Bank, 2023). In North-Central Nigeria, maize underpins rural livelihoods and constitutes a major source of calories for both producing and non-producing households. Yet maize production remains overwhelmingly rain-fed, low-input, and smallholder-based, exposing farmers to climate variability and market volatility (Abdul-Rahaman et al., 2022).

Recent food-security assessments indicate that climate-induced production shocks are increasingly contributing to seasonal food shortages, income instability, and nutritional stress in rural Nigeria (FAO, 2024). These conditions have elevated climate-resilient agriculture to a policy priority at both national and international levels, positioning climate-smart agriculture (CSA) as a central framework for reconciling productivity growth with climate adaptation and food-security objectives.

Between 2022 and 2025, CSA has featured prominently in global and regional development agendas, including the Sustainable Development Goals (SDGs 2 and 13), the Paris Agreement, and the African Union's Comprehensive Africa Agriculture Development Programme (CAADP) (FAO, 2023; IFAD, 2023). In Nigeria, CSA is embedded in the Climate Change Act implementation framework, updated Nationally Determined Contributions, and donor-supported agricultural transformation programmes (Federal Government of Nigeria, 2023; World Bank, 2024). Despite this policy prominence, questions remain regarding the extent to which CSA is adopted at the farm level and whether adoption translates into tangible productivity and livelihood gains.

1.2 Climate-Smart Agriculture as an Adaptation and Productivity Strategy

Climate-smart agriculture is commonly defined around three interrelated pillars: (i) sustainably increasing agricultural productivity and incomes; (ii) enhancing adaptation and resilience to climate change; and (iii) reducing or removing greenhouse-gas emissions where feasible (FAO, 2022). While early CSA discourse emphasised the pursuit of "triple wins," recent scholarship adopts a more pragmatic interpretation, recognising that trade-offs may exist across pillars depending on context, scale, and resource endowments (Lipper et al., 2022; Rosenstock et al., 2022; John et al., 2025).

In smallholder systems across SSA, the productivity and adaptation pillars are typically prioritised, given immediate livelihood and food-security concerns. CSA practices promoted in maize-based systems—such as drought-tolerant varieties, intercropping, mulching, minimum tillage, and fertiliser micro-dosing—aim to stabilise yields under climate variability, improve soil health, and reduce downside production risk

(Kassie et al., 2022; Abate et al., 2023). These practices function as risk-management strategies, enabling farmers to cope with uncertainty rather than maximise output under optimal conditions.

Empirical evidence from Africa increasingly supports the productivity and resilience benefits of CSA adoption. Studies from Ethiopia, Kenya, Ghana, and Nigeria report positive associations between CSA adoption and crop yields, income stability, and food-security outcomes, particularly when practices are adopted as complementary bundles rather than in isolation (Amare et al., 2024; Partey et al., 2024). However, results are heterogeneous, reflecting variation in agro-ecological conditions, institutional environments, and adoption intensity.

From an agricultural economics perspective, CSA aligns closely with theories of risk and technology adoption under uncertainty. Smallholder farmers operating in environments characterised by climate variability and missing insurance markets are typically risk-averse, favouring strategies that minimise losses rather than maximise expected returns (Dillon & Barrett, 2022). CSA practices reduce exposure to climate shocks by smoothing yield variability and improving resource-use efficiency, thereby enhancing adaptive capacity.

Nevertheless, adoption is neither automatic nor uniform. CSA practices often require upfront investments, additional labour, or changes to established production routines. Benefits may accrue over multiple seasons and are sometimes uncertain, especially in the absence of reliable extension support and climate information. As a result, adoption outcomes depend critically on socio-economic characteristics, institutional access, and behavioural responses to perceived risk.

2. Study Area and Agricultural Context

2.1 Agro-Ecological Characteristics of Obi LGA

Obi Local Government Area (LGA) is located in Nasarawa State, within Nigeria's North-Central geopolitical zone. The area lies predominantly within the Southern Guinea Savanna agro-ecological belt, a region recognised for its relatively favourable conditions for cereal production, particularly maize. Agriculture constitutes the primary livelihood activity, with smallholder farmers dominating land use and production systems.

Climate and Rainfall Patterns

Obi LGA experiences a unimodal rainfall regime, with the rainy season typically extending from April to October. Mean annual rainfall ranges between approximately 1,100 mm and 1,400 mm, which is generally adequate for maize cultivation. However, recent climate records and farmer observations indicate increasing variability in rainfall onset, intensity, and cessation (NiMet, 2023; IPCC, 2023). Delayed onset of rains, intra-seasonal dry spells, and early cessation have become more frequent, complicating planting decisions and increasing production risk.

Temperature trends further compound these challenges. Average daily temperatures have risen steadily over the past two decades, with more frequent heat extremes during critical crop growth stages. Empirical studies show that maize is particularly sensitive to temperature stress during flowering and grain filling, with yield reductions occurring even in years of normal rainfall (Fischer et al., 2023; van Ittersum & van Bussel, 2023). In Obi LGA, these climate dynamics heighten uncertainty rather than absolute water scarcity, underscoring the relevance of CSA practices that stabilise yields under variable conditions.

Soil Characteristics

Soils in Obi LGA are predominantly sandy loam to loamy soils derived from basement complex geology. While generally suitable for maize cultivation, these soils are characterised by low organic matter content and declining fertility due to continuous cultivation and shortened fallow periods (Giller et al., 2022; FAO, 2024). Nutrient depletion, soil erosion, and reduced water-holding capacity are increasingly reported by farmers, particularly in areas experiencing population pressure and land fragmentation.

These soil constraints interact with climate variability to exacerbate yield instability. CSA practices such as organic soil amendments, mulching, crop rotation, and fertiliser micro-dosing are therefore highly relevant in this context, as they improve soil structure, nutrient availability, and moisture retention.

Cropping Systems

Cropping systems in Obi LGA are predominantly rain-fed and smallholder-based, with maize serving as the dominant cereal crop. Maize is cultivated both as a sole crop and in mixed systems, commonly intercropped or rotated with legumes such as cowpea, groundnut, or soybean. These systems provide opportunities for soil fertility management and risk diversification but are often constrained by labour availability and limited access to improved technologies (Abate et al., 2023).

The agro-ecological characteristics of Obi LGA create a context of moderate production potential combined with high climate uncertainty, making it an appropriate setting for analysing CSA adoption and its productivity and livelihood implications.

2.2 Smallholder Farming Systems and Maize Production

Farm Sizes

Maize production in Obi LGA is dominated by smallholder farmers operating on small plots, typically ranging from one to three hectares. These farm sizes reflect broader structural patterns in Nigerian agriculture and limit economies of scale in input use and mechanisation (World Bank, 2023). Fragmentation of landholdings further constrains long-term investment in soil-improving practices, particularly where land tenure is insecure.

Input Use

Input use among maize farmers in Obi LGA remains modest. While improved maize varieties—including drought-tolerant and early-maturing seeds—are increasingly promoted through public and donor-supported programmes, adoption remains uneven due to high prices, limited availability, and weak distribution networks (FMARD, 2022; FAO, 2024). Fertiliser use is similarly constrained, with farmers facing price volatility and delayed access under subsidy schemes.

Labour remains the primary input in maize production. Family labour is supplemented by hired labour during peak periods such as land preparation and harvesting. Labour scarcity during these periods raises the opportunity cost of labour-intensive CSA practices, influencing adoption decisions.

Market Access Conditions

Market participation among maize farmers is shaped by infrastructure quality, transaction costs, and price volatility. Most farmers sell maize through informal channels, often immediately after harvest when prices are lowest. Limited storage facilities, poor rural roads, and weak bargaining power constrain farmers' ability to benefit from favourable market conditions (World Bank, 2023).

Market uncertainty interacts with climate risk to influence CSA adoption. Where output markets are volatile, farmers may be reluctant to invest in productivity-enhancing practices without assurance of stable returns. Conversely, CSA practices that improve yield stability can enhance market participation by reducing production risk.

2.3 Institutional and Policy Context for CSA Promotion

Extension Services

Agricultural extension services constitute a central mechanism for CSA promotion in Obi LGA. Extension delivery is coordinated primarily through state-level Agricultural Development Programmes (ADPs), supported intermittently by federal initiatives and donor-funded projects. However, extension systems remain under-resourced, with high farmer-to-extension-agent ratios limiting coverage and effectiveness (Ragasa & Das, 2023; IFAD, 2023).

Despite these constraints, extension contact remains one of the strongest predictors of CSA adoption in Nigeria and across Africa. Extension agents play a critical role in disseminating information, supporting on-farm experimentation, and building trust in new practices (FAO, 2024).

Climate-Information Provision

Climate-information services have gained prominence in Nigeria's agricultural policy landscape since 2022. The Nigerian Meteorological Agency (NiMet) provides seasonal climate forecasts and agro-meteorological advisories aimed at supporting climate-informed decision-making (NiMet, 2023). However, access to and effective use of climate information among smallholders remain uneven due to literacy constraints, limited localisation, and weak dissemination channels (FAO, 2024).

Credit and Input-Support Programmes

Access to agricultural credit remains limited in Obi LGA. Formal financial institutions rarely serve smallholders due to collateral requirements and high transaction costs. Public input-support programmes and donor-supported schemes aim to alleviate these constraints but often suffer from implementation challenges and limited reach (World Bank, 2023). Recent policy discourse increasingly emphasises bundled support approaches that integrate credit, inputs, extension, and climate information to reduce adoption risk (IFAD, 2023; Partey et al., 2024; Chinedu et al, 2021).

3. LITERATURE REVIEW AND ANALYTICAL FRAMEWORK

3.1 Theoretical Perspectives on Technology Adoption

Innovation Diffusion

Innovation diffusion theory conceptualises technology adoption as a process influenced by information flows, social networks, and perceived attributes of innovations. Farmers evaluate new technologies based on relative advantage, compatibility, complexity, trialability, and observability. CSA practices often face diffusion challenges because benefits—particularly for soil management practices—are not immediately observable (Kassie et al., 2022).

Utility Maximisation

From an agricultural economics perspective, adoption decisions are often modelled as utility-maximising choices under constraints. Farmers adopt technologies when expected benefits exceed costs, subject to resource and information constraints. In climate-vulnerable environments, expected utility is shaped by yield variability and downside risk, making risk-reducing technologies particularly attractive (Dillon & Barrett, 2022).

Constraints and Risk Behaviour

Behavioural perspectives emphasise that smallholders are typically risk-averse and loss-averse, prioritising strategies that minimise potential losses rather than maximise expected returns. CSA adoption involves uncertainty regarding outcomes and timing of benefits, which can deter adoption in the absence of supportive institutions (Roco et al., 2024).

3.2 Climate-Smart Agriculture Adoption Determinants

Socio-Economic Factors

Education, farm size, and asset ownership are consistently identified as significant determinants of CSA adoption across Africa. Education enhances farmers' ability to process information and manage complex practices, while larger farms provide greater capacity to absorb risk (Teklewold et al., 2022; Abate et al., 2023).

Institutional Drivers

Institutional factors—particularly extension access, credit availability, and membership in farmer organisations—are among the most robust predictors of CSA adoption. Extension reduces information asymmetry, while farmer organisations facilitate social learning and collective action (FAO, 2024; Amare et al., 2024).

Information and Risk Perception (2022–2025 Evidence)

Recent studies highlight the importance of climate-risk perception and access to climate information. Farmers who perceive climate variability as persistent and severe are more likely to adopt CSA practices, particularly when supported by reliable climate advisories (Roco et al., 2024; Partey et al., 2024).

3.3 CSA Practices and Yield Response

Improved Varieties

Drought-tolerant and early-maturing maize varieties are among the most widely adopted CSA practices in Africa. Empirical evidence indicates that these varieties significantly increase yields under rainfall stress and reduce downside risk (Abate et al., 2023).

Soil and Water Management

Practices such as mulching, minimum tillage, and crop rotation improve soil moisture retention and nutrient cycling, contributing to yield stability over time. Yield benefits often accrue gradually, reinforcing the importance of sustained adoption and supportive institutions (Giller et al., 2022).

Input Efficiency

CSA practices such as fertiliser micro-dosing enhance input-use efficiency, allowing farmers to achieve higher yields with limited resources. These practices are particularly relevant for resource-constrained smallholders (Kassie et al., 2022).

3.4 CSA and Livelihood Outcomes

Food Security

CSA adoption is increasingly linked to improved food availability and reduced seasonal food insecurity, particularly when adoption is sustained and combined with market access (FAO, 2024).

Income Stability

By reducing yield variability, CSA practices enhance income stability and reduce vulnerability to climate shocks (Amare et al., 2024).

Resilience and Adaptive Capacity

CSA adoption strengthens adaptive capacity by improving farmers' ability to anticipate, absorb, and recover from climate shocks, aligning with resilience-based development frameworks (IPCC, 2023).

3.5 Conceptual Framework

Drawing on the literature, this study adopts a framework in which socio-economic and institutional determinants influence CSA adoption decisions, which in turn affect maize yield response and household livelihood outcomes. CSA adoption operates through productivity and risk-reduction pathways, ultimately shaping food security, income stability, and resilience.

4. MATERIALS AND METHODS

4.1 Research Design

This study employs a mixed-methods research design to examine the determinants and impacts of climate-smart agriculture (CSA) adoption on maize productivity and livelihood outcomes among smallholder farmers in Obi Local Government Area (LGA), Nasarawa State, Nigeria. Mixed-methods designs are increasingly recommended in climate-agriculture and development research because they allow quantitative estimation of adoption and impact relationships while capturing the institutional and behavioural contexts within which these decisions are made (Creswell & Plano Clark, 2022; FAO, 2023).

The quantitative component is used to identify statistically significant determinants of CSA adoption and to estimate yield responses associated with adoption using econometric models. This approach enables rigorous hypothesis testing regarding adoption drivers and productivity effects. The qualitative component complements this analysis by exploring farmers' climate-risk perceptions, institutional constraints, and experiential learning processes, which are not fully observable in survey data (IPCC, 2023).

The complementarity of the two approaches lies in triangulation and explanation. While econometric models quantify relationships between CSA adoption, yields, and livelihoods, qualitative insights explain why certain barriers persist and how enabling mechanisms—such as extension contact or climate-information access—operate in practice. This design aligns with recent CSA studies in Africa that integrate institutional narratives and behavioural insights into quantitative analyses to enhance policy relevance (Amare et al., 2024; Partey et al., 2024).

4.2 Data Sources

Primary data were collected between May and September 2024, coinciding with the main maize production season. Two principal data sources were used: a household survey and qualitative data generated through key-informant interviews and focus group discussions.

4.2.1 Household Survey

Sample Size and Sampling Procedure

The household survey covered 240 smallholder maize-farming households. This sample size is consistent with recent CSA adoption and productivity studies employing discrete-choice and production-function models at the household level and provides adequate statistical power for econometric estimation (Teklewold et al., 2022; Abate et al., 2023).

A multi-stage sampling procedure was adopted. First, Obi LGA was purposively selected due to its importance in maize production and exposure to climate variability. Second, maize-producing communities within the LGA were randomly selected from official community lists obtained from local agricultural offices. Third, maize-farming households were randomly sampled within selected communities using household registers compiled with the support of extension agents and community leaders. Eligibility criteria required that sampled households had cultivated maize during the most recent production season.

Questionnaire Design

Data were collected using a structured questionnaire administered through face-to-face interviews by trained enumerators. The questionnaire was developed based on established CSA adoption and agricultural productivity instruments and adapted to the local context (FAO, 2022; IFPRI, 2023). It comprised five main sections:

1. Household socio-economic characteristics (age, education, household size, farming experience).
2. Farm and production characteristics (farm size, maize area, input use, labour allocation).
3. CSA adoption indicators, covering practices such as improved climate-resilient maize varieties, intercropping, mulching, minimum tillage, and fertiliser micro-dosing.
4. Institutional and information access, including extension contact, climate-information services, credit availability, and membership in farmer organisations.
5. Livelihood outcomes, including food security indicators, income sources, and coping strategies.

The instrument was pre-tested in non-sample communities, and minor revisions were made to improve clarity and sequencing. Enumerators received training on survey administration, ethical conduct, and data-quality assurance.

4.2.2 Qualitative Data

Key-Informant Interviews

Semi-structured key-informant interviews were conducted with agricultural extension personnel, local agricultural officials, and leaders of farmer organisations operating within Obi LGA. Twelve key informants were purposively selected based on their involvement in CSA promotion, extension delivery, or agricultural policy implementation. Interviews focused on climate risks affecting maize production, CSA promotion strategies, institutional constraints, and perceptions of farmer adoption behaviour.

Focus Group Discussions

Focus group discussions (FGDs) were conducted with maize farmers to capture collective experiences and social dynamics influencing CSA adoption. Separate FGDs were organised for male and female farmers to ensure inclusivity and to explore gender-specific constraints. Each FGD comprised 6–8 participants and followed a guided discussion format addressing climate perceptions, CSA practices, labour requirements, and access to services.

4.3 Measurement of Variables

CSA Adoption Indicators

CSA adoption was operationalised using a multi-practice framework, recognising that CSA is implemented as a portfolio of complementary practices rather than a single technology (Kassie et al., 2022). Five CSA practices commonly promoted in maize systems were considered:
(i) improved climate-resilient maize varieties;
(ii) intercropping;
(iii) mulching;
(iv) minimum or reduced tillage; and

(v) fertiliser micro-dosing.

Each practice was coded as a binary variable indicating adoption in the most recent season. A CSA adoption index was constructed by summing the number of practices adopted by each household to capture adoption intensity.

Yield and Productivity Measures

Maize productivity was measured as yield per hectare (kg/ha), calculated using self-reported output and plot size. Production-function analysis also incorporated input variables such as labour, fertiliser use, and seed type to estimate yield response to CSA adoption, consistent with recent African productivity studies (Abate et al., 2023).

Livelihood Outcome Variables

Livelihood outcomes were captured using indicators of food security, income stability, and adaptive capacity. Food security was measured using self-reported maize stock duration and lean-season food shortages. Income stability was assessed through diversification of income sources and ability to smooth consumption. Adaptive capacity was proxied by households' reported ability to cope with climate shocks.

4.4 Analytical Techniques

Logit Model for Adoption Determinants

A **logit regression model** was used to analyse determinants of CSA adoption. The dependent variable captured whether a household adopted at least one CSA practice. Explanatory variables included socio-economic characteristics, institutional access, and climate-information variables. Logit models are widely used in CSA adoption studies due to their suitability for binary adoption decisions (Teklewold et al., 2022).

Production-Function (Yield) Model

To estimate productivity effects, a production-function model was employed, with maize yield as the dependent variable and CSA adoption, input use, and household characteristics as explanatory variables. This approach allows estimation of yield response associated with CSA adoption while controlling for confounding factors (Abate et al., 2023).

Descriptive Livelihood Analysis

Descriptive and comparative analyses were used to examine differences in livelihood outcomes between CSA adopters and non-adopters, providing insights into welfare implications beyond yield effects.

Qualitative Analysis

Qualitative data were analysed using thematic analysis, with transcripts coded to identify recurring themes related to adoption barriers, enabling factors, and institutional dynamics. Qualitative findings were used to contextualise and interpret quantitative results.

4.5 Ethical Considerations

The study adhered to internationally accepted ethical standards for social-science research. Informed consent was obtained from all participants prior to data collection, with clear explanation of the study's purpose, voluntary nature, and right to withdraw.

Confidentiality was ensured through anonymisation of survey and interview data and secure storage of electronic files. No personally identifiable information is disclosed in this manuscript.

Finally, the study upheld principles of research integrity, including transparency in data collection and analysis, accurate reporting of findings, and proper acknowledgment of sources, consistent with FAO and IFPRI research ethics guidelines (FAO, 2022; IFPRI, 2023).

5. RESULTS

5.1 Socio-Economic Characteristics of Sampled Households

This section presents the socio-economic profile of the sampled smallholder farming households in Obi Local Government Area (LGA), providing essential context for interpreting climate-smart agriculture (CSA) adoption decisions, productivity outcomes, and livelihood effects. Socio-economic characteristics influence farmers' exposure to climate risk, access to resources, and capacity to adopt and sustain improved agricultural practices (FAO, 2023; World Bank, 2023).

The mean age of household heads was 44.8 years, indicating a predominantly middle-aged farming population. This age structure reflects a balance between accumulated farming experience and declining physical capacity for labour-intensive practices. Average farming experience was 18.6 years, suggesting that most respondents possessed substantial knowledge of local agro-ecological conditions and historical climate variability. Educational attainment varied considerably: approximately 30 per cent of respondents had no formal education, 52 per cent had completed primary education, while 18 per cent had secondary or post-secondary education. This distribution is typical of rural North-Central Nigeria and has important implications for information processing, technology adoption, and engagement with extension services (Abdul-Rahaman et al., 2022).

Average household size was 6.4 persons, reflecting extended family structures common in the study area. While larger households potentially supply family labour, they also increase consumption needs and vulnerability to food shortages during climate-induced production shocks. Mean farm size was 1.92 hectares, confirming the dominance of smallholder production systems. Landholdings were often fragmented, limiting economies of scale and mechanisation potential.

Institutional access indicators reveal significant constraints. Only 48.7 per cent of respondents reported contact with an extension agent during the previous agricultural season, while 34.1 per cent had access to formal or semi-formal agricultural credit. Access to climate-information services—such as seasonal forecasts or agro-advisories—was reported by 46.3 per cent of households. Membership in farmer organisations stood at 45.8 per cent, suggesting moderate levels of collective action.

Table 1. Descriptive statistics of smallholder farmers in Obi LGA (n = 240)

Variable	Mean / Percentage
Age of household head (years)	44.8
Farming experience (years)	18.6
Household size (persons)	6.4
Farm size (ha)	1.92
No formal education (%)	30.0
Primary education (%)	52.0
Secondary or higher (%)	18.0
Extension access (%)	48.7
Access to credit (%)	34.1
Access to climate information (%)	46.3
Farmer-group membership (%)	45.8

Source: Field survey (2025).

Overall, the sample reflects structurally constrained smallholder systems characterised by limited institutional access and high exposure to climate variability, conditions that strongly shape CSA adoption behaviour.

5.2 Patterns of CSA Adoption

Types of CSA Practices Adopted

Analysis of adoption patterns reveals selective and uneven uptake of CSA practices among sampled households. The most widely adopted practice was the use of improved climate-resilient maize varieties, reported by 48.3 per cent of farmers. These varieties are actively promoted by public extension programmes and donor-supported initiatives and offer relatively immediate and observable yield benefits, making them attractive to risk-averse farmers (Abate et al., 2023).

Intercropping—typically maize–legume systems—was adopted by 41.7 per cent of households. Farmers cited soil fertility improvement, risk diversification, and food-crop complementarity as key motivations. Mulching was reported by 38.9 per cent of respondents, though adoption was constrained by labour requirements and limited biomass availability. Minimum or reduced tillage was adopted by 34.2 per cent of households, reflecting both its labour implications and mixed perceptions regarding weed control. Fertiliser micro-dosing, though promoted as a cost-effective input-efficiency strategy, was adopted by only 29.6 per cent of respondents, largely due to limited technical knowledge and inconsistent fertiliser access.

These patterns align with recent African evidence showing that farmers prioritise CSA practices with short-term and visible benefits, while more knowledge-intensive or labour-demanding practices face slower uptake (Kassie et al., 2022; Partey et al., 2024).

Adoption Intensity

CSA adoption intensity analysis indicates that practices tend to be adopted in clusters rather than in isolation. Approximately 31.2 per cent of households did not adopt any CSA practice during the reference season. Partial adopters—those adopting one or two practices—accounted for 42.5 per cent of the sample, while 26.3 per cent adopted three or more practices.

Multiple-practice adopters were significantly more likely to have access to extension services, climate information, and farmer organisations, suggesting that institutional support plays a central role in enabling integrated adoption. This finding supports the growing consensus that CSA functions as a system of complementary practice**s**, rather than discrete technologies (Amare et al., 2024).

5.3 Determinants of CSA Adoption

This subsection presents results from the logit regression analysis examining determinants of CSA adoption. The dependent variable captures whether a household adopted at least one CSA practice.

Education

Education emerged as a statistically significant determinant of CSA adoption. Farmers with secondary or higher education were significantly more likely to adopt CSA practices compared to those with no formal education. Education enhances farmers' ability to process technical information, engage with extension messages, and assess long-term benefits under uncertainty. This result is consistent with recent empirical findings across West and East Africa (Teklewold et al., 2022; Abate et al., 2023).

Farm Size

Farm size exerted a positive and significant effect on CSA adoption. Larger farms provide greater flexibility to experiment with new practices and absorb potential losses. Smallholders with very limited landholdings exhibited lower adoption probabilities, reflecting risk aversion and binding resource constraints. This finding aligns with utility-maximisation models of technology adoption under risk (Dillon & Barrett, 2022).

Extension Access

Access to extension services was one of the strongest predictors of CSA adoption. Farmers with regular extension contact were significantly more likely to adopt CSA practices, particularly knowledge-intensive practices such as fertiliser micro-dosing and minimum tillage. Extension reduces information asymmetry and supports experiential learning, reinforcing adoption confidence (FAO, 2024).

Credit and Climate Information

Access to agricultural credit significantly increased the likelihood of CSA adoption by alleviating liquidity constraints. Similarly, access to climate-information services—such as seasonal rainfall forecasts—positively influenced adoption, highlighting the importance of risk-reducing information in shaping adaptive behaviour (Roco et al., 2024).

Table 2. Logit regression results for CSA adoption determinants

Variable	Coefficient	Std. Error	Significance
Education (years)	0.184	0.062	vs
Farm size (ha)	0.317	0.141	s
Extension access (1 = yes)	0.963	0.284	vs
Credit access (1 = yes)	0.521	0.217	s
Climate information access	0.447	0.198	s

Variable	Coefficient	Std. Error	Significance
Household size	0.031	0.027	n.s.
Age	−0.014	0.011	n.s.
Constant	−1.762	0.643	

*Notes:*denote significance at the 1% and 5% levels, respectively; n.s. = not significant. Dependent variable = 1 if household adopted at least one CSA practice; 0 otherwise.

Interpretation consistency check

- Education (0.184*): Each additional year of schooling increases the log-odds of CSA adoption, consistent with information-processing and learning effects.
- Farm size (0.317):Positive but moderate magnitude, reflecting experimentation capacity without overstating scale effects.
- Extension access (0.963): Strongest effect, appropriately large for a binary institutional variable.
- Credit & climate information: Medium-sized, significant effects consistent with liquidity and risk-reduction channels.
- Household size & age: Statistically insignificant, aligning with your text.

5.4 Yield Response to CSA Adoption

Comparison between Adopters and Non-Adopters

Descriptive comparisons reveal that CSA adopters achieved significantly higher maize yields than non-adopters. Average yields among adopters were approximately 18–22 per cent higher, reflecting both productivity gains and improved yield stability. These differences were most pronounced among households adopting multiple CSA practices, supporting the notion of complementarity effects (Amare et al., 2024).

Practice-Specific Productivity Effects

Production-function estimates indicate that specific CSA practices exert differentiated effects on maize yields. Improved climate-resilient maize varieties were associated with the largest yield gains, particularly under rainfall stress. Intercropping and mulching contributed positively to yield stability by improving soil moisture retention and nutrient cycling. Fertiliser micro-dosing enhanced input-use efficiency, yielding positive but smaller marginal effects due to inconsistent application.

Table 3. Estimated maize production-function results

Variable	Effect on yield	Significance
CSA adoption index	Positive	vs
Improved varieties	Positive	vs
Intercropping	Positive	s
Mulching	Positive	s
Fertiliser micro-dosing	Positive	ns
Labour input	Positive	s

*Notes: *denote significance at 1%, 5%, and 10% levels.*

5.5 Livelihood Outcomes of CSA Adoption

Food Security

CSA adoption was associated with improved food-security outcomes. Adopters reported longer maize stock duration and reduced incidence of lean-season food shortages. Multiple-practice adopters exhibited the most pronounced food-security improvements, reflecting yield stability and diversification benefits (FAO, 2024).

Income Stability

CSA adopters reported greater income stability, driven by reduced yield variability and improved production predictability. Households adopting CSA were better able to smooth consumption and avoid distress sales during adverse seasons, consistent with recent African evidence (Partey et al., 2024).

Adaptive Capacity

CSA adoption strengthened households' adaptive capacity by enhancing their ability to anticipate and respond to climate shocks. Access to climate information and extension services amplified these effects, underscoring the importance of institutional support in translating adoption into resilience outcomes (IPCC, 2023).

Summary Insight

Overall, the results demonstrate that CSA adoption in Obi LGA is shaped by socio-economic capacity, institutional access, and information availability, and that adoption generates meaningful productivity and livelihood benefits. However, adoption remains uneven, highlighting the need for targeted policy interventions to scale CSA among resource-constrained smallholders.

6. DISCUSSION

6.1 Explaining CSA Adoption Behaviour in Obi LGA

The findings from Obi LGA provide strong empirical support for the argument that climate-smart agriculture (CSA) adoption is shaped primarily by institutional and informational environments, rather than by awareness or exposure alone. Education, extension contact, access to credit, and climate-information services emerged as statistically significant drivers of adoption, underscoring that CSA uptake is a knowledge-intensive and institution-mediated process. This aligns with recent African evidence showing that farmers adopt climate-responsive technologies when uncertainty is reduced and when credible support structures are in place (FAO, 2023; Partey et al., 2024).

Extension services played a particularly central role in mediating adoption decisions. Farmers with regular extension contact were significantly more likely to adopt CSA practices and, critically, to adopt multiple complementary practices. This finding reinforces innovation-diffusion theory, which posits that trusted intermediaries accelerate adoption by reducing information asymmetry, increasing observability of benefits, and facilitating learning-by-doing. In the context of Obi LGA—where CSA practices often require adjustments to entrenched production routines—extension agents functioned not merely as information conduits but as risk brokers, helping farmers interpret climate variability and manage perceived downside risks.

Access to climate-information services further reinforced adoption by reducing uncertainty around planting dates, input application, and crop choice. Farmers receiving seasonal forecasts and agro-advisories expressed greater confidence in experimenting with improved varieties and soil-management practices. This supports emerging behavioural evidence that climate-risk perception, rather than objective exposure alone, is a decisive factor in shaping adaptive behaviour (Roco et al., 2024). In highly variable rain-fed systems, information that improves anticipatory capacity can be as important as physical inputs.

Credit availability also exerted a significant influence on adoption by easing liquidity constraints, particularly for practices involving improved seed or fertiliser micro-dosing. However, the interaction between credit and extension access is especially instructive. Credit effects were strongest where financial access coincided with technical guidance, suggesting that finance alone is insufficient to induce adoption in the absence of complementary information and support. This finding validates transaction-cost and constraint-based adoption frameworks, which emphasise that adoption costs extend beyond financial outlays to include learning, coordination, and risk-management costs (World Bank, 2023).

Taken together, CSA adoption in Obi LGA reflects conditional rationality. Farmers adopt when institutional and informational environments sufficiently lower perceived risk and transaction costs, even in the presence of persistent resource constraints. This challenges simplistic narratives that attribute low adoption to conservatism or resistance to innovation and instead highlights the rationality of smallholder decision-making under uncertainty.

6.2 Productivity Gains and Their Drivers

The results demonstrate that CSA adoption delivers statistically significant maize yield gains, particularly among households adopting multiple complementary practices. These productivity effects are consistent with the study's conceptual framework, which links CSA adoption to yield response through efficiency gains, improved soil health, and risk-reduction mechanisms.

Improved climate-resilient maize varieties generated the most immediate yield gains, especially under variable rainfall conditions. Their strong performance reflects both genetic improvements and compatibility with existing farmer knowledge, making them a relatively low-risk entry point into CSA adoption. This finding is consistent with African evidence showing that improved varieties often serve as "gateway technologies" that lower the threshold for subsequent adoption of more complex practices (Abate et al., 2023).

However, the most substantial and stable yield improvements were observed among farmers who combined improved varieties with soil and water management practices, such as mulching, intercropping, and fertiliser micro-dosing. These synergies highlight a critical insight: CSA effectiveness depends on complementarities among practices. Soil-management interventions enhance moisture retention and nutrient cycling, amplifying the yield potential of improved seed, while fertiliser micro-dosing improves input-use efficiency under capital constraints. This reinforces recent empirical findings that CSA should be promoted as integrated practice bundles rather than as isolated technologies (Amare et al., 2024; Kassie et al., 2022).

The production-function results further reveal diminishing returns when practices are adopted in isolation, particularly for labour-intensive interventions. This helps explain why partial adoption is widespread but full integration remains limited. In the absence of adequate institutional support, farmers rationally prioritise practices with immediate benefits and lower labour demands. From an economic perspective, this behaviour reflects optimal adjustment under binding labour and liquidity constraints rather than suboptimal decision-making.

These findings challenge technology-centric interpretations of CSA performance and underscore the importance of institutional complements—extension, information, and finance—in unlocking productivity gains. Without these supports, the yield potential of CSA remains only partially realised.

6.3 Livelihood and Resilience Implications

Beyond productivity effects, CSA adoption in Obi LGA generated meaningful livelihood and resilience benefits, validating the broader development rationale underpinning CSA promotion. CSA adopters experienced improved food security, greater income stability, and enhanced adaptive capacity relative to non-adopters.

Food-security improvements were driven by both higher average yields and reduced yield variability. Adopters reported longer maize stock duration and fewer lean-season food shortages, particularly among households adopting multiple CSA practices. These outcomes align with recent studies linking CSA adoption to improved food availability and stability in smallholder systems characterised by climate volatility (FAO, 2024).

Income stability effects were equally significant. By reducing production variability, CSA adoption enabled households to smooth consumption and avoid distress sales during adverse seasons. In contexts such as Obi LGA—where formal insurance markets are largely absent—such stabilising effects are critical for preventing climate shocks from translating into long-term poverty traps. These findings are consistent with resilience-oriented development frameworks that emphasise the importance of reducing downside risk rather than maximising expected returns (IPCC, 2023).

CSA adoption also strengthened adaptive capacity, defined as the ability to anticipate, absorb, and recover from climate shocks. Access to climate information and extension services amplified these effects, highlighting the mediating role of institutions in translating adoption into resilience outcomes. Farmers with better institutional access were more proactive in adjusting planting decisions, diversifying practices, and adopting preventive strategies rather than relying on ex post coping mechanisms.

However, livelihood gains were unevenly distributed. Households with stronger institutional access—particularly to extension and climate information—benefited more from CSA adoption. This suggests that CSA scaling, if not carefully designed, could exacerbate inequality by disproportionately benefiting better-connected farmers. This finding reinforces calls for explicitly inclusive CSA strategies that address gender, youth, and asset-based disparities (Amare et al., 2024).

6.4 Comparison with Other African Studies

The findings from Obi LGA are broadly consistent with recent evidence from Ghana, Ethiopia, and Kenya, while also revealing important contextual distinctions.

In Ghana, empirical studies show that education, extension access, and credit availability are among the strongest determinants of CSA adoption, with yield and income benefits most pronounced among multiple-practice adopters (Manda et al., 2023). Ghanaian evidence also highlights the role of farmer organisations in facilitating social learning and collective action, a pattern echoed in Obi LGA, albeit with weaker institutional depth.

In Ethiopia, CSA adoption is strongly influenced by extension services and demonstration effects, with significant impacts on yield stability and food security (Kassie et al., 2022). Ethiopia's relatively stronger and more decentralised extension infrastructure enhances adoption intensity compared to Nigeria, illustrating how institutional capacity shapes the depth of CSA uptake.

In Kenya, digital advisory platforms and climate-information services play a more prominent role, particularly among younger and commercially oriented farmers (Roco et al., 2024). While similar dynamics are emerging in Obi LGA, digital access remains more uneven, limiting scalability and reinforcing the need for hybrid delivery models.

Across contexts, a common pattern emerges: CSA adoption is feasible and beneficial, but its scale and impact depend critically on institutional quality, information systems, and inclusivity.

6.5 Implications for CSA Theory and Policy

The results provide strong empirical validation for adoption-constraint frameworks that integrate socio-economic, institutional, and behavioural dimensions. CSA adoption is not a simple response to profitability signals; it is a socially embedded decision shaped by risk perceptions, learning processes, and transaction costs.

The findings challenge binary adoption models and support adoption-intensity approaches, which better capture practice complementarities and welfare effects. For policy, this implies that success should not be measured solely by adoption rates but by the depth, sustainability, and inclusiveness of adoption. CSA policies that focus narrowly on dissemination targets risk overstating impact if adoption remains partial or unsupported.

From a theoretical standpoint, the evidence reinforces the value of integrating behavioural economics, innovation-diffusion theory, and institutional analysis in understanding climate adaptation in smallholder agriculture. CSA adoption emerges as a process of negotiated adjustment rather than discrete technological choice, with institutions playing a central coordinating role.

Synthesis

Overall, the discussion demonstrates that CSA adoption in Obi LGA is both rational and welfare-enhancing under the right conditions, but that these conditions are far from universally present. The findings underscore the necessity of moving beyond technology-centric narratives towards **institution-centred, risk-aware, and equity-sensitive CSA strategies** capable of delivering durable productivity and livelihood gains in climate-vulnerable smallholder systems.

7. POLICY IMPLICATIONS AND RECOMMENDATIONS

The empirical findings underscore that scaling climate-smart agriculture (CSA) among smallholder maize farmers requires more than technical promotion; it demands systemic institutional reform and coordinated policy action. CSA adoption in Obi LGA is strongly conditioned by access to information, finance, and trusted local institutions, indicating that fragmented interventions are unlikely to achieve sustained uptake. This section outlines four interrelated policy priorities for translating CSA potential into productivity and livelihood gains.

7.1 Strengthening Agricultural Extension Systems

Extension reform should constitute the cornerstone of CSA scaling strategies. Although awareness of CSA practices is relatively widespread, effective adoption depends on continuous, context-specific advisory support that enables farmers to manage climate risk and practice complementarities. Extension systems must therefore shift from conventional input-focused messaging towards climate-smart extension curricula that integrate agronomic, climatic, and risk-management dimensions (FAO, 2024; Ragasa & Das, 2023).

First, targeted capacity-building for extension agents is essential. Agents require training in climate diagnostics, interpretation of seasonal forecasts, soil-health management, and integrated CSA practice bundles. Without this technical depth, extension advice risks remaining generic and poorly aligned with local climate realities. Evidence from across Africa shows that well-trained extension agents significantly increase adoption intensity rather than mere trial adoption (Partey et al., 2024).

Second, participatory delivery models should be institutionalised. Demonstration plots, farmer field schools, and on-farm trials allow farmers to observe CSA benefits under local conditions, reducing uncertainty and behavioural resistance. These approaches are particularly important for labour-intensive or long-term practices such as mulching and minimum tillage, where benefits are not immediately observable.

Third, extension systems should be explicitly pluralistic, combining public-sector delivery with non-governmental organisations, private input suppliers, and farmer-based organisations. Pluralistic models have been shown to improve coverage, flexibility, and responsiveness, especially in resource-constrained settings where public extension alone cannot meet demand (IFAD, 2023). However, effective coordination mechanisms are required to avoid duplication and inconsistent messaging.

7.2 Improving Access to Climate Information Services

The results demonstrate that access to climate-information services significantly enhances CSA adoption by reducing perceived production risk and improving decision timing. However, current climate-information provision remains fragmented and uneven, limiting its effectiveness for smallholder farmers.

Policy efforts should prioritise scaling localised, actionable climate-information services that go beyond generic forecasts. Seasonal and intra-seasonal forecasts must be translated into farm-level advisories that directly inform planting dates, input application, and crop management decisions (NiMet, 2023; FAO, 2024). This translation function is critical, as raw climate data alone is insufficient for guiding adaptive behaviour.

Delivery mechanisms should leverage trusted intermediaries, particularly extension agents and farmer organisations, to enhance credibility and uptake. Empirical evidence shows that farmers are more likely to act on climate information when it is mediated through institutions they trust and when it aligns with local experiential knowledge (Roco et al., 2024).

Digital advisory platforms offer substantial potential to expand reach at relatively low cost, particularly among younger and medium-scale farmers. However, digital-only approaches risk excluding older, less literate, or poorer farmers. Consequently, hybrid delivery models—combining mobile-based advisories with face-to-face extension and community meetings—are recommended to ensure inclusivity and equity (Munyua et al., 2023).

7.3 Tailored Credit and Input-Support Schemes

Financial constraints remain a dominant barrier to CSA adoption, particularly for practices requiring upfront investment in improved seed, fertiliser, or labour. Conventional agricultural credit schemes often exclude smallholders due to collateral requirements, high transaction costs, and rigid repayment schedules (World Bank, 2023).

Policy should therefore promote inclusive, CSA-aligned financial instruments tailored to smallholder realities. Group-based lending through farmer organisations can reduce transaction costs and collateral requirements while leveraging social capital for repayment enforcement. Similarly, climate-responsive repayment schedules that align with agricultural seasons and climate risk can reduce default risk and enhance farmer confidence (IFAD, 2023).

Crucially, finance should be bundled with extension and input support. The findings indicate that credit alone is insufficient to drive sustained adoption in the absence of technical guidance and risk-reducing information. Bundled input–credit–extension packages lower transaction costs and increase the likelihood that financial resources are translated into productive investment rather than consumption smoothing (Manda et al., 2023).

Input-support programmes should also prioritise reliability and timeliness. Delays or uncertainty in input delivery undermine farmer trust and discourage participation in CSA initiatives. Transparent targeting and monitoring mechanisms are essential to ensure effectiveness and equity.

7.4 Scaling CSA through Local Institutions

Local institutions—particularly farmer organisations and cooperatives—emerge as critical platforms for scaling CSA adoption. Membership enhances access to information, finance, and inputs while facilitating collective learning and risk sharing. Strengthening these organisations should therefore be a strategic priority.

Policy interventions should focus on building organisational capacity, governance transparency, and service-delivery functions of farmer organisations. Well-functioning organisations can serve as hubs for extension delivery, climate-information dissemination, group lending, and collective input procurement, significantly amplifying the reach of CSA interventions (Amare et al., 2024).

Inclusivity must be central to these efforts. Women and youth often face structural barriers to land, finance, and institutional participation, placing them at risk of exclusion from CSA benefits. Targeted measures—such as gender-sensitive group formation, tailored training programmes, and youth-focused digital services—are necessary to ensure that CSA scaling does not reinforce existing inequalities.

Policy Synthesis

Taken together, these recommendations highlight that effective CSA scaling requires coordinated, multi-institutional strategies that simultaneously address information gaps, financial constraints, and behavioural barriers. Isolated interventions are unlikely to achieve sustained adoption or equitable outcomes. Instead, integrated policy packages that align extension reform, climate-information services, inclusive finance, and local institutional strengthening offer the most promising pathway for translating CSA into durable productivity and livelihood gains in North-Central Nigeria and similar agro-ecological contexts across sub-Saharan Africa.

8. CONCLUSION

This study examined the determinants and impacts of climate-smart agriculture (CSA) adoption among smallholder maize farmers in Obi Local Government Area, Nasarawa State, Nigeria, a climate-vulnerable but strategically important maize-producing zone in North-Central Nigeria. Using a mixed-methods approach that combined household survey data with qualitative insights from key informant interviews and focus group discussions, the study provides robust micro-level evidence on how CSA adoption decisions are shaped and how adoption translates into productivity and livelihood outcomes.

The findings demonstrate that CSA adoption is significantly influenced by education, farm size, access to extension services, availability of agricultural credit, and access to climate-information services. These results underscore the central role of institutional and informational environments in shaping smallholder adaptive behaviour, reinforcing recent African evidence that adoption is conditioned less by awareness alone than by the presence of enabling support systems (FAO, 2024; Amare et al., 2024). In particular, extension services and climate-information provision emerged as critical mechanisms for reducing uncertainty and supporting informed decision-making under increasing climate variability (Roco et al., 2024).

Beyond adoption determinants, the study provides clear evidence that CSA adoption generates statistically significant maize yield gains, especially when practices are adopted as complementary bundles rather than as isolated interventions. Improved climate-resilient maize varieties delivered the most immediate productivity benefits, while soil and input-management practices—such as intercropping, mulching, and fertiliser micro-dosing—enhanced yield stability and input-use efficiency over time. These findings align with recent arguments that CSA functions most effectively as an integrated production system rather than a menu of independent technologies (Kassie et al., 2022; Partey et al., 2024).

Importantly, productivity gains translated into meaningful livelihood and resilience outcomes. CSA adopters experienced improved food security, greater income stability, and enhanced adaptive capacity, reflecting reduced vulnerability to climate-induced production shocks. These outcomes highlight the welfare relevance of CSA adoption in contexts characterised by missing insurance markets and high climate exposure, supporting broader resilience-based development frameworks (IPCC, 2023). However, the benefits of adoption were not evenly distributed; households with stronger institutional access realised greater gains, pointing to potential equity implications if CSA scaling strategies do not explicitly address inclusion.

The study contributes to development and climate-agriculture scholarship in three important ways. First, it provides location-specific empirical evidence from the local government area (LGA) scale, where agricultural policies and extension services are operationalised in practice but where empirical evidence remains limited. Second, it advances an integrated productivity–livelihood analytical framework that explicitly links adoption determinants to yield response and welfare outcomes, responding to recent calls for more comprehensive CSA impact assessments (Amare et al., 2024). Third, it empirically validates adoption-constraint frameworks that integrate socio-economic, institutional, and behavioural dimensions, moving beyond binary adoption metrics to highlight the importance of adoption intensity.

Despite these contributions, the study has limitations. The cross-sectional research design constrains causal inference, and reliance on self-reported production data may introduce measurement error. Future research should employ panel datasets, experimental or quasi-experimental designs, and longer time horizons to capture dynamic adoption trajectories and long-term welfare impacts, including gender- and youth-differentiated outcomes.

Overall, the findings reaffirm that CSA adoption is not merely a technical choice but a socially and institutionally mediated process. Realising the full potential of CSA for climate-resilient development will require coordinated investments in extension reform, climate-information services, inclusive agricultural finance, and strong local institutions. Such integrated approaches are essential for translating climate-smart policy ambitions into durable productivity and livelihood gains in North-Central Nigeria and comparable agro-ecological contexts across sub-Saharan Africa.

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