Extension Communication and Adoption of Climate-Smart Agriculture among Smallholder Maize Farmers in Zaria, Nigeria

Ahmed Abubakar,[a]*, Yakubu, Sulaiman[b], & Yahaya OgbeAgbaji,[c]
[ab]Department of Mass Communication, Ahmadu Bello University, Zaria, Kaduna State, Nigeria
[c]NTA Television College, Jos, Plateau State, Nigeria
*Corresponding email: ahmed.abubakar98@yahoo.com

Abstract
The persistently low adoption of climate-smart agricultural (CSA) practices in Zaria highlights a critical communication gap, raising concerns about how extension strategies influence farmers' awareness, trust, and uptake of innovations under climate change. This study, conducted in Zaria, Kaduna State, focused on registered smallholder maize farmers under the Kaduna Agricultural Development Agency (KADA). A descriptive survey design was employed, with 500 respondents selected through multi-stage sampling. Data were gathered using structured questionnaires and key informant interviews (KIIs) with extension officers, and instrument reliability was confirmed (Cronbach's Alpha = 0.82). Quantitative data were analysed using descriptive statistics and guided by Rogers' Diffusion of Innovations Theory (2003). The findings revealed that the adoption of climate-smart agricultural practices among smallholder maize farmers in Zaria LGA is influenced by gender, age, education, experience, and farm size, highlighting the need for inclusive and tailored extension strategies that engage both men and women. The study also revealed that a multi-channel extension strategy combining interpersonal visits, group engagements, and mass-media tools effectively promotes adoption, with interactive methods needed to address limitations such as low digital literacy and network constraints. The study concludes that the adoption of climate-smart agricultural practices among smallholder maize farmers in Zaria LGA is shaped by demographic factors and extension strategies, underscoring the need for inclusive, multi-channel, and participatory approaches that integrate interpersonal, group-based, and mass-media methods to build trust, enhance learning, and overcome barriers such as low digital literacy and network limitations. The study recommends adopting a multi-channel extension approach that combines interpersonal visits, group-based engagements, and mass-media or digital tools, while ensuring interactive and participatory methods to build trust, facilitate peer learning, and address barriers such as low digital literacy and network constraints.

Keywords: Climate-smart agriculture, communication, strategies, extension, smallholder-maize farmers

Introduction

Climate change is increasingly reshaping agriculture across sub-Saharan Africa, where millions of smallholder farmers depend on rain-fed systems for their livelihoods. Rising temperatures, erratic rainfall, floods, and prolonged droughts have intensified production risks, threatening food security and rural incomes (IPCC, 2023). In Northern Nigeria, particularly in Kaduna State, irregular rainfall and dry spells have shortened growing seasons and reduced yields of staple crops such as maize and sorghum. Despite the region's contribution to national maize output, productivity among smallholder farmers remains below potential due to recurrent droughts and limited access to adaptive technologies.

To address these challenges, Climate-Smart Agriculture (CSA) has gained prominence as an integrated approach that enhances productivity, strengthens resilience, and reduces greenhouse gas emissions. CSA practices, such as drought-tolerant crop varieties, efficient soil and water management, and agroforestry, are increasingly promoted by research and extension institutions (FAO, 2023). Yet, the success of these innovations depends not only on their technical merits but also on how effectively they are communicated to and understood by farmers. Extension communication plays a pivotal role in this process by translating scientific knowledge into practical, locally relevant information through farm visits, field demonstrations, radio programmes, and digital platforms.

In Zaria, for instance, institutions such as the National Agricultural Extension and Research Liaison Services (NAERLS) and the Institute for Agricultural Research (IAR) have disseminated CSA messages through community engagement and media outreach. However, despite these efforts, the adoption of climate-smart practices remains low. Studies attribute this to weak farmer–extension linkages, inadequate message framing, and limited participation in communication processes (Okwuokenye & Okoh, 2020; Suleiman & Awotodunbo, 2021). This situation suggests that the challenge is not merely the availability of technologies but the effectiveness of the communication strategies used to promote them. Understanding how communication channels, message design, and farmer perceptions influence adoption is therefore crucial. Guided by Rogers' Diffusion of Innovations Theory, this study explores how extension communication facilitates or constrains the uptake of climate-smart agricultural practices among smallholder maize farmers in Zaria, Kaduna State. Against this background, the study seeks to:

i. To identify the extension communication strategies employed in promoting climate-smart agricultural practices among smallholder maize farmers in Zaria LGA.
ii. To assess smallholder maize farmers' perceptions of the effectiveness of these communication strategies in Zaria LGA.
iii. To determine the extent of adoption of climate-smart agricultural practices among smallholder maize farmers in Zaria LGA.

Conceptual Review

Climate-Smart Agriculture (CSA) and Its Relevance to Smallholder Farmers

Climate-smart agriculture (CSA) offers a strategic response to climate change by pursuing three core goals: sustainable productivity, resilience building, and greenhouse gas reduction. Its relevance to smallholder farmers in sub-Saharan Africa lies in its potential to address declining yields, food insecurity, and income instability (Saadu et al., 2024). Evidence from Nigeria shows that practices such as crop diversification, drought-tolerant varieties, conservation agriculture, and agroforestry improve productivity and food security (Shehu, 2023; Saadu et al., 2024), with notable benefits for women farmers in terms of empowerment (Ilesanmi, 2020). However, adoption remains constrained by weak extension services and inadequate financial support.

Comparative studies across Africa confirm that the effectiveness of CSA depends on enabling conditions. In Botswana and Zambia, CSA boosted maize yields and household income (Mpinda et al., 2025), while in Tanzania and Kenya, adoption was driven by education, training, and access to information, leading to improved food security (Erick et al., 2025). In South Africa, access to credit and extension services influenced adoption intensity (MDPI, n.d.). In Nigeria's North-Central and North-West zones, systemic barriers such as financial exclusion and weak extension networks remain critical challenges (CABI Digital Library, n.d.). While most studies emphasise productivity and adaptation, the mitigation potential of CSA such as carbon

sequestration through agroforestryhas received limited attention, signalling an important research and policy gap.

Extension Communication Strategies for Promoting Climate-Smart Agricultural Practices

Extension communication is central to promoting climate-smart agriculture by linking research outputs with smallholder farmers and enhancing knowledge, skills, and adoption decisions (Billah, 2024). Its effectiveness directly shapes productivity, resilience, and sustainability outcomes. Farmers' exposure to multiple communication channels including radio, television, farmer field schools, and print media broadens reach across varying literacy levels, thereby promoting inclusivity (Billah, 2024). Mobile and digital platforms increasingly complement traditional methods. In rural settings, mobile phones provide timely and tailored advice, significantly boosting CSA adoption (Jones, 2023). Similarly, digital advisory services in Ghana have improved farmers' knowledge and uptake of CSA technologies (Asante, 2024). Nonetheless, human-mediated strategies remain indispensable. Trust-building, field demonstrations, and participatory training foster practical learning and sustained behavioural change (Mungai, 2024; Hassan, 2024). Socio-cultural and institutional contexts also determine the effectiveness of extension communication. Cultural norms and local practices shape farmers' receptivity, highlighting the need for culturally adapted communication approaches (Gikunda, 2022). Institutional frameworks, government programmes, and cooperative support create enabling environments that sustain CSA adoption (Olabanji & Chitakira, 2025). Thus, effective extension communication blends traditional and digital tools, human interaction, cultural sensitivity, and institutional support to achieve widespread and sustainable adoption.

Adoption of Climate-Smart Agricultural Practices among Smallholder Farmers in Nigeria

Climate change presents major risks to Nigerian smallholder farmers, including erratic rainfall, recurring droughts, and soil degradation. Climate-smart agriculture provides an integrated response by promoting higher yields, resilience, and food security through practices such as drought-tolerant seeds, agroforestry, intercropping, soil fertility management, water conservation, and ICT-based advisory tools. However, adoption is not automatic; it is shaped by farmers' socio-economic realities. Studies show that education and social positioning strongly influence adoption. Farmers with higher levels of education are better able to understand CSA concepts, apply technical knowledge, and take calculated risks. Similarly, gender and marital status affect access to resources: male and married farmers often have greater land rights and decision-making power, giving them an advantage in CSA adoption (Aniche & McKee, 2023; Ojo, 2023). This suggests that beyond technical capacity, social factors determine who benefits first and most.

Institutional and extension support is equally critical. Farmers who receive consistent guidance, demonstrations, and participatory training are more likely to integrate CSA practices into their farming systems. For example, crop rotation, organic fertilisation, and water management techniques are best learned through repeated extension contact rather than one-off advice (Nazifi et al., 2024). This underscores the importance of hands-on learning and trust-building between farmers and extension personnel. The benefits of CSA adoption are well documented and include higher yields, improved household food security, increased incomes, and more sustainable land and livestock management (Nazifi et al., 2024; Kanu & Przezbórska-Skobiej, 2025). In some cases, CSA also supports livelihood diversification, such as integrating sustainable practices into agritourism, demonstrating its broader economic and environmental value. However, significant barriers remain. Many farmers lack access to affordable credit, limiting their ability to invest in inputs such as improved seeds or irrigation tools. Weak extension coverage leaves farmers insufficiently informed about CSA benefits, while cultural norms such as

resistance to altering traditional farming practices also slow adoption. These barriers vary across regions, indicating the need for context-specific strategies, including credit and input subsidies in some areas, targeted awareness campaigns in others, and gender-focused support in communities where women farmers face systemic disadvantages.

Review of Related Empirical Studies

Empirical studies consistently demonstrate that the adoption of climate-smart agriculture (CSA) among smallholder farmers in Nigeria is shaped by a combination of socio-economic, institutional, and communication-related factors. Recent evidence highlights the growing relevance of digital and extension-driven innovations in enhancing climate resilience, while also revealing persistent structural barriers. Mudashir et al. (2025) examined the role of artificial intelligence (AI) in advancing CSA through extension services in Kaduna State and found generally positive farmer perceptions of AI applications, particularly in climate forecasting, pest and disease detection, and early warning systems. However, limited access to extension services, poor internet connectivity, and high costs constrained adoption. Education level, cooperative membership, and extension contact emerged as strong predictors of AI adoption, underscoring the importance of knowledge dissemination structures and social networks. While the study advances understanding of emerging technologies in agriculture, it largely focuses on technological readiness, paying limited attention to how communication strategies shape farmers' trust and sustained use of innovations.

Similarly, Saadu et al. (2024) reported high levels of CSA adoption among smallholder farmers in North-Western Nigeria, with adopters recording significant gains in productivity, income, and food security. Adoption was influenced by age, awareness of climate change, and membership of agricultural associations, reinforcing the role of information access and social capital. However, the study emphasised economic outcomes more than the communication processes through which CSA knowledge is transmitted, leaving a gap in understanding how extension messaging influences behavioural change over time. Bayei et al. (2024) focused specifically on maize farmers in Kaduna State and identified gender, marital status, income, farming experience, cooperative membership, and access to credit as key determinants of CSA adoption intensity. Their findings confirm that adoption is not uniform but occurs at varying levels, shaped by both individual and institutional factors. While the study provides valuable insights into adoption patterns, it offers limited examination of the effectiveness of specific extension communication channels in facilitating adoption decisions.

Taken together, these studies affirm that CSA adoption among smallholder farmers is influenced not only by technological availability and socio-economic characteristics but also by institutional support systems, particularly extension services. However, existing literature tends to treat extension services as a background variable rather than critically interrogating how communication strategies, channel combinations, message framing, and participatory engagement affect farmers' understanding, trust, and sustained adoption of CSA practices. This gap justifies the present study's focus on extension communication as a central mechanism shaping the adoption of climate-smart agricultural practices among smallholder maize farmers in Zaria, Kaduna State.

Theoretical Framework

This study is anchored on Rogers' Diffusion of Innovations Theory, which explains how new ideas and technologies spread through a social system over time via communication channels (Rogers, 2003). Originally influential in post–World War II agricultural extension, the theory remains relevant for understanding the adoption of climate-smart agricultural practices (CSAPs)

among smallholder maize farmers in Kaduna State. The theory outlines five stages of adoption knowledge, persuasion, decision, implementation, and confirmation through which extension communication provides information, demonstrations, and social support (Extension Practice Agrifutures, 2023). Rogers also classifies adopters as innovators, early adopters, early majority, late majority, and laggards, showing how adoption typically moves from risk-takers to the wider population. In Kaduna State, opinion leaders among maize farmers often act as early adopters, influencing others through networks and cooperatives. Tailored extension communication that reduces complexity and enhances the compatibility, trialability, and observability of CSAPs can accelerate diffusion. Combining interpersonal methods with mass media and digital platforms ensures wider reach and inclusivity (Baig et al., 2005). Although the theory best fits less complex innovations, it offers a practical framework for planning and evaluating extension strategies. Addressing barriers such as limited resources, education gaps, and trust deficits is essential for improving adoption and building resilience.

Methodology

A descriptive survey design was adopted to collect quantitative data on farmers' perceptions, communication exposure, and adoption of climate-smart agricultural (CSA) practices. The population comprised all registered smallholder maize farmers under the Kaduna Agricultural Development Agency (KADA) in 2024, totalling approximately 5,480 farmers. Using Yamane's (1967) formula at a 95% confidence level and a 5% margin of error, a sample size of 500 respondents (about 9% of the population) was determined to ensure adequate representation across gender and farm-size categories. A multi-stage sampling technique was employed. Zaria LGA was stratified into its agricultural zones (Sabon Gari, Giwa, and Soba blocks). Key maize-producing villages such as Samaru, Wusasa, Shika, and Danmagaji were purposively selected based on production intensity and accessibility. Respondents were then selected from each village using proportionate random sampling. Data were collected using a structured questionnaire covering demographic characteristics, awareness of CSA practices, sources and effectiveness of extension communication, adoption levels, and perceived barriers, using a five-point Likert scale for key constructs.

For the qualitative aspect, twelve key informant interviews (KIIs) were conducted with selected experts: five extension officers from KADA, three communication officers from the National Agricultural Extension and Research Liaison Services (NAERLS), two community-based agricultural facilitators, and two leaders of farmer cooperatives. These informants were purposively chosen because of their direct involvement in the design, coordination, and delivery of extension communication strategies promoting CSA among maize farmers. The instruments were validated by three experts from Ahmadu Bello University, Zaria, for clarity, relevance, and alignment with the study objectives. Reliability was established through a pilot test with 30 farmers in Igabi LGA, yielding a Cronbach's Alpha of 0.82, indicating high internal consistency. Trained field assistants administered the questionnaires face-to-face. Ethical clearance was obtained from the Faculty Research Ethics Committee of Ahmadu Bello University, and permission was granted by KADA. Quantitative data were analysed using SPSS version 26. Descriptive statistics, including frequencies and percentages, were used to summarise respondents' awareness, and adoption levels of CSA practices.

Data Presentation and Analysis

Table 1. Demographic Characteristics of Smallholder Maize Farmers (N = 500)

Demographic Variable	Category	Frequency (n)	Percentage (%)
Gender	Male	320	64.0
	Female	180	36.0
Age (years)	Below 30	60	12.0
	30–39	110	22.0
	40–49	160	32.0
	50 and above	170	34.0
Educational Level	No formal education	90	18.0
	Primary education	150	30.0
	Secondary education	170	34.0
	Tertiary education	90	18.0
Farming Experience (years)	below 5	70	14.0
	5–9	100	20.0
	10–14	140	28.0
	15 and above	190	38.0
Farm Size (hectares)	Less than 1 ha	160	32.0
	1–2 ha	210	42.0
	Above 2 ha	130	26.0
Total		500	100.0

A total of 500 smallholder maize farmers participated in the study. As shown in Table 1, the demographic profile reveals a predominance of male respondents (64%), indicating that maize production in Zaria LGA is largely male-dominated, though women (36%) also play a significant role, particularly in post-harvest and marketing activities. In terms of age distribution, most respondents were within the productive age range of 40 years and above (66%), comprising 32% aged 40–49 years and 34% aged 50 years and above. This suggests that maize farming in the area is managed mainly by mature and experienced adults, which may influence their readiness to adopt climate-smart agricultural (CSA) practices. Regarding educational level, 82% of the farmers had at least some formal education, with 30% attaining primary education, 34% secondary, and 18% tertiary. This relatively high literacy rate implies that the majority can comprehend agricultural extension messages, which enhances the potential for effective communication and technology adoption. The data on farming experience show that a substantial proportion (66%) had 10 or more years of experience, demonstrating that most farmers are well-versed in maize production. Such experience is valuable for assessing changes in climate patterns and implementing adaptive practices. Concerning farm size, 42% cultivated between 1–2 hectares, 32% farmed less than 1 hectare, and 26% cultivated more than 2 hectares. This distribution confirms that the respondents are primarily smallholder farmers, aligning with the study's focus.

Extension Communication Strategies for Promoting CSAPs

Data from Key Informant Interviews (KIIs) on Extension Communication Strategies. Twelve KIIs were conducted with key stakeholders: five extension officers from KADA, three communication officers from NAERLS, two community-based agricultural facilitators, and two leaders of farmer cooperatives. These informants were purposively selected for their direct involvement in designing, coordinating, and implementing communication strategies to promote climate-smart agricultural practices (CSAPs) among smallholder maize farmers in Zaria LGA. The KII guide was structured around Objective ii: To identify the extension communication strategies employed in promoting CSAPs. Thematic analysis revealed three primary strategies: interpersonal communication, group-based approaches, and mass-media dissemination, each with specific

strengths and constraints. On Interpersonal Communication, Farm visits and on-site demonstrations were reported by six informants (50%), primarily extension officers, as the most effective approach. This method enables direct interaction, trust-building, and practical learning. One officer explained:

> *When we go to their farms, we do not just talk; we make sure farmers understand better when they see a practice done on their own soil.* (K2)

While highly effective for less literate farmers, its reach is constrained by limited personnel and logistical challenges. Interpersonal communication is most impactful when complemented by group-based and mass-media strategies, reinforcing understanding and adoption. On Group-Based Approaches, Five informants (42%), including extension officers and facilitators, highlighted farmers' group meetings and demonstration plots as key strategies for promoting peer learning, collective action, and practical application of CSAPs. Group platforms facilitate discussion, experience-sharing, and problem-solving. One facilitator explained:

> *During group meetings, farmers share experiences and learn from each other. Demonstrations within these groups make practices easier to understand and apply on their own farms.* (F1)

Despite their effectiveness, high operational costs and scheduling conflicts sometimes limit participation. Group-based approaches often overlap with interpersonal methods, as demonstrations within group settings reinforce practical learning and adoption.

On Mass-Media Dissemination, Seven informants (58%) emphasized the use of radio programs, mobile phone messages, and SMS to reach farmers, especially in remote areas. Radio was highlighted as the most accessible medium, while SMS and mobile alerts provided timely reminders and weather information. One officer noted:

> *In this area, radio is still the most reliable medium. Farmers tune in daily, and many mention what they heard on air when we meet them.* (K5)

Television and printed materials were also used but reported as less effective due to limited access and comprehension challenges. Informants stressed that mass-media strategies are most effective when integrated with interpersonal and group-based approaches, enhancing coverage while reinforcing practical understanding among farmers.

Table 2. Farmers' Perceptions of the Effectiveness of Extension Communication Strategies

Extension Communication Strategy	Frequency (n=500)	Percentage (%)
Extension Agent Visits (very effective)	160	32.0
Radio Programs	120	24.0
Farmers' Group Meetings	90	18.0
Demonstration Plots/Field Days	60	12.0
Mobile Phone/SMS	40	8.0
Television Programs	20	4.0
Posters/Printed Materials	10	2.0
Total	500	100.0

Table 2 presents data on farmers' perceptions of the effectiveness of various extension communication strategies in promoting climate-smart agricultural practices (CSAPs). The findings reveal that extension agent visits were perceived as the most effective strategy (32.0%), followed by radio programs (24.0%) and farmers' group meetings (18.0%). These results underscore the continuing importance of interpersonal communication and radio as dominant channels for agricultural extension. Demonstration plots (12.0%) and mobile phone/SMS messages (8.0%) were rated moderately effective, while television programs (4.0%) and printed materials (2.0%)

were viewed as least effective. Overall, the results indicate that farmers value communication approaches that facilitate direct interaction, trust-building, and accessibility, whereas the effectiveness of ICT- and print-based methods remains limited by challenges such as literacy levels, network coverage, and access constraints.

Table 3. Adoption of Climate-Smart Agricultural Practices among Smallholder Maize

Climate-Smart Agricultural Practice	Frequency (n=500)	Percentage (%)
Use of Improved/Drought-Tolerant Maize Varieties	150	30.0
Crop Rotation	100	20.0
Mulching/Soil Cover	70	14.0
Agroforestry/Tree Planting	60	12.0
Conservation Tillage	50	10.0
Organic Manure/Composting	40	8.0
Integrated Pest Management (IPM)	30	6.0
Total	500	100.0

Table 3 presents the extent of adoption of climate-smart agricultural (CSA) practices among smallholder maize farmers in Zaria LGA. The findings indicate that the use of improved or drought-tolerant maize varieties was the most widely adopted practice (30.0%), followed by crop rotation (20.0%) and mulching (14.0%). Other practices such as agroforestry (12.0%), conservation tillage (10.0%), organic manure application (8.0%), and integrated pest management (IPM) (6.0%) recorded comparatively lower adoption rates. Overall, the results suggest a moderate level of CSA adoption, reflecting farmers' preference for practices that are less capital-intensive, easily adaptable, and offer immediate yield benefits. Conversely, practices requiring higher technical skills or greater financial investment tend to attract fewer adopters, underscoring the need for enhanced extension support and capacity building to scale up adoption of comprehensive CSA strategies.

Discussion of Findings

This study examined how extension communication strategies influence the adoption of climate-smart agricultural practices (CSAPs) among smallholder maize farmers in Zaria LGA. Findings from the Key Informant Interviews (KIIs) substantiate the quantitative results, offering a coherent explanation of how communication channels shape awareness, persuasion, and adoption decisions. Overall, the results demonstrate that adoption is best facilitated through a complementary mix of interpersonal, group-based, and mass-media communication channels, consistent with Rogers' (2003) Diffusion of Innovations Theory. Interpersonal communication emerged as the most influential extension strategy. Six informants (50%), mainly extension officers, identified farm visits and on-site demonstrations as their most effective tools. This dominance reflects Rogers' proposition that interpersonal channels are most persuasive at the persuasion and decision stages of adoption, where potential adopters seek reassurance, clarification, and evidence of benefits. Direct engagement enhances trust, observability, and trialability, key attributes that reduce uncertainty and encourage adoption of CSAPs. In contexts such as rural Zaria, where literacy levels and access to digital technologies are limited, face-to-face interaction remains indispensable. This finding aligns with Ejem et al. (2023), who argue that demonstration-based extension approaches are critical for translating abstract climate information into practical, actionable farming practices.

Group-based communication strategies, reported by five informants (42%), including farmer group meetings and demonstration plots, further reinforced adoption through social learning and peer influence. These platforms enable early adopters and opinion leaders to share experiences,

validate innovations, and collectively address challenges. From a diffusion perspective, such interactions accelerate movement from early adopters to the early majority by normalising new practices within the social system. This supports Nnamdi et al. (2021), who found that participatory, community-driven extension models foster collective ownership and sustain long-term adoption of agricultural innovations.

Mass-media channels particularly radio were identified by seven informants (58%) as essential for creating broad awareness across dispersed farming populations. Radio remains a trusted and accessible medium due to its affordability, use of local languages, and wide rural reach. In line with Rogers' theory, mass media were most effective at the knowledge stage of diffusion, introducing CSAPs and shaping initial awareness. This finding corroborates Obinna and Okorie (2023), who emphasise radio's effectiveness in overcoming literacy barriers in agricultural communication. However, the findings also show that mass media alone are insufficient for sustained adoption, underscoring the importance of interpersonal reinforcement to translate awareness into practice. The growing use of mobile phone-based communication, such as SMS and voice alerts, reflects a gradual digital transition within extension systems. While these tools enhance timeliness and reach, their effectiveness is constrained by poor network coverage, cost, and low digital literacy among farmers. These limitations mirror findings by Ejem et al. (2023) and highlight the need for blended communication strategies that integrate digital tools with traditional extension methods to maximise both reach and depth of understanding.

Quantitative findings (Table 3) further support these patterns, with farmers ranking extension agent visits as the most effective strategy (32.0%), followed by radio programmes (24.0%) and farmer group meetings (18.0%). These preferences underscore farmers' reliance on communication channels that allow interaction, contextualisation, and immediate feedback. Demonstration plots (12.0%) and mobile phone/SMS (8.0%) were rated moderately effective, while television (4.0%) and printed materials (2.0%) were least effective, largely due to infrastructural constraints, limited electricity access, and low literacy levels. Collectively, these results reaffirm that communication strategies grounded in participation, accessibility, and local relevance are most effective in influencing behavioural change in rural agricultural settings (Aker, 2011).

Regarding adoption patterns (Table 4), the most widely adopted CSAP was the use of improved or drought-tolerant maize varieties (30.0%), followed by crop rotation (20.0%) and mulching (14.0%). These practices offer immediate, visible benefits such as yield stability and reduced vulnerability to erratic rainfall, making them more attractive to risk-averse smallholder farmers. This finding aligns with Wossen et al. (2017), who reported significant yield improvements and reduced downside risk among adopters of drought-tolerant maize in Nigeria. From a diffusion standpoint, these practices possess high relative advantage and compatibility with existing farming systems, facilitating quicker adoption. On the other hand, more technically demanding practices such as agroforestry (12.0%), conservation tillage (10.0%), organic manure application (8.0%), and integrated pest management (6.0%) recorded lower adoption rates. These practices require higher labour input, technical knowledge, or financial investment, increasing perceived complexity and risk. This supports Rogers' assertion that innovations perceived as complex or incompatible with existing practices diffuse more slowly. Evidence from Oyetunde-Usman and Shee (2023) further indicates that limited access to inputs and training constrains adoption, even where awareness exists.

Conclusion

The study concludes that the adoption of climate-smart agricultural practices (CSAPs) among smallholder maize farmers in Zaria LGA is shaped by a combination of demographic factors and extension communication strategies. Predominantly male, mature, educated, and experienced farmers leverage indigenous knowledge and literacy to assess and adopt innovations, highlighting the importance of inclusive extension approaches that actively engage both men and women. It also indicate that a multi-channel communication model, combining interpersonal visits, group-based engagements, and mass-media dissemination effectively promotes adoption, as interpersonal and group strategies foster trust, peer learning, observability, and trialability, consistent with Rogers' Diffusion of Innovations Theory (2003). While mass media and emerging digital tools enhance awareness and reach, their effectiveness is constrained by low digital literacy and network limitations, underscoring the need for blended strategies that integrate interactive and participatory methods. Collectively, these insights suggest that agricultural extension programs should prioritize context-sensitive, participatory, and capacity-building interventions to reduce barriers, enhance practical application of CSAPs, and improve resilience and sustainability of smallholder maize production in Zaria LGA.

Recommendations

i. The study recommends that agricultural extension programs in Zaria LGA should adopt inclusive, tailored strategies that engage all farmers and leverage their knowledge and experience to improve the uptake of climate-smart agricultural practices.
ii. The study recommends adopting a multi-channel extension approach that combines interpersonal visits, group-based engagements, and mass-media or digital tools, ensuring interactive and participatory methods to build trust, facilitate peer learning, and overcome barriers such as low digital literacy and network constraints.
iii. Extension services should integrate interactive and participatory methods with digital tools to address low literacy and network challenges, ensuring effective farmer engagement and application of innovations.
iv. Agricultural extension programs in Zaria LGA should implement a multi-channel approach combining interpersonal visits, group-based engagements, and mass-media dissemination to enhance adoption of climate-smart agricultural practices.

References

Aker, J. C. (2011). Dial "A" for agriculture: A review of information and communication technologies for agricultural extension in developing countries. *Agricultural Economics, 42*(6), 631–647. https://doi.org/10.1111/j.1574-0862.2011.00545.x

Aniche, A., & McKee, K. E. (2023). *What factors affect the adoption of climate-smart agriculture by smallholder farmers in Nigeria?* [Poster presentation]. KIETS Climate Leaders Program Fall Symposium, Raleigh, USA. https://climateleaders.kenan.ncsu.edu/wp-content/uploads/sites/87/2023/10/Aniche Poster-2023.pdf

Asante, M., Ma, X., Prah, D., & Temoso, A. (2024). Digital advisory services and climate-smart agriculture adoption among maize farmers in Ghana. *Journal of Agricultural Extension and Development, 12*(3), 45–60.

Baig, M. B., Aldosari, F., & Salem, K. (2005). Agricultural extension methods and adoption behaviour. *Journal of Agricultural Extension and Rural Development, 2*(5), 150–158.

Bayei, J. D., Abu, I. A., Haruna, U., & Jibril, S. A. (2024). Factors influencing the adoption of climate-smart agricultural practices among maize farmers in Kaduna State, Nigeria. *African Journal of Agriculture and Allied Sciences, 4*(1), 13.

Billah, M. M. (2024). Farmers' exposure to communication media in receiving agricultural extension and rural advisory services for farm sustainability. *Sustainable Agriculture Extension, 2*(1), 1–15.

Ejem, A. A., Aremu, C., Akerele-Popoola, O. O., Ibiwoye, T. I., & Olaniran, A. F. (2023). Perspectives on communicating 21st-century agricultural innovations to Nigerian rural farmers. *Journal of Agriculture and Food Research, 11*, 100511. https://doi.org/10.1016/j.jafr.2023.100511

Erick, S. B., Mbwambo, J. M., & Salanga, M. (2025). Adoption of climate-smart agricultural practices among smallholder leafy vegetable agripreneurs in semi-arid regions: A bibliometric review. *African Journal of Agricultural Science and Technology, 5*(1), 1–15. https://doi.org/10.1007/s44279-025-00293-6

Extension Practice Agrifutures. (2023). *Diffusion of innovations theory—Adoption and diffusion*. https://extension-practice-agrifutures.com.au/resource/diffusion-of-innovations-theory adoption-and-diffusion/

Food and Agriculture Organization. (2023). *Climate-smart agriculture sourcebook*. FAO. https://www.fao.org/climate-smart-agriculture-sourcebook

Gikunda, A. (2022). Cultural and socio-economic influences on adoption of climate-smart agricultural practices in smallholder farming communities. *African Journal of Rural Development, 9*(2), 77–91.

Hassan, L. (2024). Education, extension programmes, and the adoption of climate-smart practices in flood-prone agricultural areas. *Journal of Climate and Agriculture, 15*(1), 23–38.

Ilesanmi, O. T. (2024). *A climate-smart agricultural productivity assessment of smallholder women farmers in farming associations in Nigeria: A mixed methods study* [Master's thesis]. Texas A&M University. https://oaktrust.library.tamu.edu/items/1af13eda-1ee8 40d8-98bd-8d5fb3108b7e

Intergovernmental Panel on Climate Change. (2014). *Climate change 2014: Impacts, adaptation, and vulnerability*. Cambridge University Press.

Issa, F. O. (2017). Agricultural extension and climate change in Nigeria: The role of communication in adaptation. *Journal of Agricultural Extension, 21*(2), 34–46. https://doi.org/10.4314/jae.v21i2.4

Jones, E. O. (2023). Mobile agricultural extension delivery and climate-smart agriculture adoption: Evidence from rural communities. *International Journal of Agricultural Technology, 14*(4), 101–116.

Kanu, I. M., & Przezbórska-Skobiej, L. (2025). Socio-economic determinants of climate-smart agriculture adoption: A novel perspective from agritourism farmers in Nigeria. *Sustainability, 17*(12), 5521. https://doi.org/10.3390/su17125521

Mpinda, M. T., Bett, H. K., & Muluvi, J. M. (2025). Determinants of adoption of climate-smart agricultural practices among smallholder maize farmers in North East District, Botswana. *Agricultural Systems, 202*, 103314. https://doi.org/10.1016/j.agsy.2025.103314

Mudashir, A. O., Beatrice, I. O., Joseph, B., Oluwamayowa, J. J., Theophilus, R., Ayoola, F. J., & Samson, O. S. (2025). The role of artificial intelligence in promoting climate-smart agriculture through extension services in Kaduna State, Nigeria. *Current Trends in Agronomy & Agricultural Research, 1*(1), 1–15.

Mungai, P. (2024). Effectiveness of extension personnel in promoting climate-smart agriculture in Central Malawi. *Journal of Agricultural Extension Studies, 11*(2), 55–70.

Nnamdi, F. N., Okechukwu, M. N., & Eze, J. N. (2021). Participatory communication and the diffusion of agricultural innovations among rural farmers in Nigeria. *Journal of Development Communication Studies, 8*(2), 45–59.

Obinna, C., & Okorie, N. (2023). Rural radio and agricultural innovation diffusion in Nigeria: A media access perspective. *African Journal of Communication Research, 12*(1), 22–38.

Obute, C. C., Agwu, A. E., & Asadu, A. N. (2021). Adoption of climate-smart agricultural practices among maize farmers in Nigeria: Implications for food security. *Journal of Agricultural Extension, 25*(4), 142–155. https://doi.org/10.4314/jae.v25i4.12

Ojo, T. O. (2023). Level of adoption of climate-smart agriculture among smallholder rice farmers in Osun State, Nigeria. *Science Progress, 106*(3), 003685042311037. https://doi.org/10.1177/003685042311037

Okwuokenye, G. F., & Okoh, R. N. (2020). Agricultural extension services and farmers' adoption of improved technologies in Kaduna State, Nigeria. *Nigerian Journal of Agricultural Economics, 10*(1), 57–68.

Olabanji, O., & Chitakira, M. (2025). Institutional support and the scaling of climate-smart agriculture innovations in Africa. *African Journal of Agricultural Policy, 7*(1), 12–29.

Oladipo, A. A., Adefila, J. O., & Danjuma, S. (2022). Determinants of farmers' adoption of climate-smart agriculture practices in Kaduna State, Nigeria. *African Journal of Agricultural Research, 18*(9), 456–466.

Olooto, F. M., Yusuf, O. J., & Akinwale, J. A. (2019). Institutional challenges to agricultural technology adoption among smallholder farmers in Nigeria. *Journal of Rural Extension and Development, 13*(2), 75–84.

Oyetunde-Usman, Z., & Shee, A. (2023). Adoption of drought-tolerant maize varieties and interrelated climate-smart agricultural practices in Nigeria. *Agriculture & Food Security, 12*, 43. https://doi.org/10.1186/s40066-023-00429-1

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). Free Press.

Saadu, B., Ibrahim, H. Y., Nazifi, B., & Mudashiru, A. (2024). Adoption of climate-smart agricultural practices and its impact on smallholder farming households in some rural areas of North-Western Nigeria. *Agricultura Tropica et Subtropica, 57*(1), 23–34. https://doi.org/10.2478/ats-2024-0003

Shehu, M. (2023). State of climate-smart agriculture (CSA) practices in the North-Central and North-West zones of Nigeria. *CABI Agriculture and Bioscience, 3*, 1–13. https://doi.org/10.1186/s43170-023-00156-4

Suleiman, Y. M., & Awotodunbo, A. (2021). Farmers' perception and adoption of climate-smart agricultural practices in Northern Nigeria. *Nigerian Journal of Rural Sociology, 21*(2), 98–110.

Wossen, T., Abdoulaye, T., Alene, A., Feleke, S., Menkir, A., & Manyong, V. (2017). Measuring the impacts of adaptation strategies to drought stress: The case of drought tolerant maize varieties. *Journal of Environmental Management, 203*(Pt. 1), 106–113. https://doi.org/10.1016/j.jenvman.2017.06.058