



PARTICIPATION IN ALTERNATIVE AGRICULTURAL EXTENSION APPROACHES AND RICE OUTPUT AMONG SMALLHOLDER FARMERS IN NIGER STATE, NIGERIA

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ABSTRACT

This study examined participation in alternative agricultural extension approaches and its relationship to rice output among smallholder farmers in Niger State, Nigeria. Specifically, the study assessed farmers' participation in alternative extension approaches and determined the effects of participation on rice output. The study adopted a three-stage sampling technique to select 238 registered rice farmers from three agricultural zones in the State. The study collected primary data through structured questionnaires and interview schedules. The study used descriptive statistics and multiple regression analysis for data analysis. The findings revealed high participation in public, public-private, and digital extension approaches, particularly in out-growers' contract schemes (98.7%), rice output aggregation (98.7%), and mobile SMS-based advisory services (97.5%). Participation was generally high across most extension approaches. The semi-log regression model was selected as the lead equation, with an R^2 of 0.5753, indicating that the explanatory variables explained 57.5% of the variation in rice output. Duration of participation, access to extension materials, exposure to demonstration plots, use of WhatsApp/social media and education significantly increased rice output, while farming experience negatively influenced output. The study concluded that alternative extension approaches significantly improved rice farmers' productivity. The study recommended strengthening digital extension platforms, expanding demonstration-based learning and promoting long-term farmer participation in extension programmes to enhance rice productivity and food security in Nigeria.

Keywords: Alternative, Approaches, Output, Participations and Rice farmers

INTRODUCTION

Rice has become one of the world's most important staple foods, providing a major source of calories and household income for millions, particularly in developing countries. In sub-Saharan Africa, the demand for rice has increased rapidly due to population growth, urbanisation and changing consumption patterns. Nigeria remains Africa's largest producer and consumer of rice. Yet, domestic production has continued to lag behind national demand despite several policy interventions and agricultural development programmes aimed at improving productivity among smallholder farmers (Arouna *et al.*, 2021). Local production systems' inability to meet growing consumption needs has sustained dependence on rice imports and heightened concerns about food security, rural poverty, and agricultural sustainability.

Smallholder rice farmers dominate rice production in Nigeria and contribute substantially to rural livelihoods, job creation, and the national food supply. However, many of these farmers operate under severe production constraints, including limited access to improved technologies, inadequate extension support, poor market integration, rising production costs and weak institutional services (Ragasa *et al.*, 2020). These challenges have contributed to low productivity, inefficient resource utilisation and unstable farm income among rural households. Among these limitations, inadequate access to effective agricultural extension services remains a major factor constraining technology adoption and improved farm performance.

Agricultural extension services play an important role in facilitating knowledge transfer, improving farm management practices and strengthening farmers' decision-making capacity. Conventional public extension systems were originally designed to disseminate agricultural innovations and provide technical support to farmers through direct interactions with extension agents. Although these systems contributed significantly to agricultural transformation in earlier decades, their effectiveness has weakened over time because of poor funding, inadequate staffing, weak institutional coordination, and limited outreach capacity. In many developing countries, including Nigeria, the ratio of extension agents to farmers remains extremely low, reducing the frequency and quality of farmer-extension interactions. Consequently, many smallholder farmers continue to rely on informal information sources that may not adequately address emerging production challenges.

The limitations of conventional public extension systems have stimulated growing interest in alternative extension approaches that are more participatory, market-oriented, and demand-driven. These approaches include Farmer Field Schools (FFS), participatory extension approaches, contract farming arrangements, private extension services, video-mediated advisory systems and cost-sharing extension models. Unlike traditional top-down extension systems, alternative approaches emphasise farmer participation, experiential learning, private-sector involvement, peer-to-peer interaction, and the integration of digital communication tools. They

are increasingly viewed as important mechanisms for improving technology dissemination, strengthening market access and enhancing the productivity of smallholder farmers.

Empirical evidence suggests that participation in alternative extension approaches can improve farmers' adoption of improved technologies, crop management practices and market participation. Digital advisory platforms and video-mediated extension services are associated with increased access to timely production information, weather forecasts, and pest management recommendations, thereby improving farm efficiency and reducing production risks. Similarly, contract farming and privatised extension services have enabled farmers to access inputs, credit facilities and output markets that support higher productivity and income generation. Studies show that farmers participating in alternative extension programmes often achieve higher yields and improved household welfare than non-participants.

Despite the growing relevance of alternative extension approaches, participation among smallholder rice farmers remains uneven and influenced by socio-economic, institutional and infrastructural factors. Access to information, education level, farm size, income status, institutional trust and availability of digital infrastructure affect farmers' ability and willingness to participate in these programmes. In many rural communities, weak institutional coordination, poor internet connectivity and inadequate financial resources continue to limit effective participation and reduce the potential benefits of these extension models. Furthermore, empirical evidence examining the effects of participation in alternative extension approaches on rice output and farm income among smallholder rice farmers remains limited in several parts of Nigeria.

Existing studies (Taylor and Bhasme, 2018; Cole and Fernando, 2021) have largely focused on technology adoption and productivity outcomes without adequately examining the broader implications of farmers' participation intensity across different alternative extension models. In addition, comparative evidence on how participation influences rice output and farm income among smallholder rice farmers remains insufficient, particularly in heterogeneous rural production environments. This creates an important research gap requiring empirical investigation. Against this background, this study examines the effects of participation in alternative extension approaches on smallholder rice farmers' output and income in Niger State, Nigeria. Specifically,

1. the study assesses the level of farmers' participation in alternative extension approaches and
2. determines the effects of participation on smallholder rice farmers' output and income.

METHODOLOGY

The study was carried out in Niger State, Nigeria. The State was created out of the former North Western State and became a fully autonomous State on 3rd February, 1976, with headquarters at

Minna. Niger State lies between latitude 8°00' and 11°30' North and longitude 3°30' and 7°40' East. It has a population of 3,954,772 with a growth rate of 2.5%; the State was estimated to have a population of 7,420,247 in 2024 (NBS, 2025). Niger State accounts for 2.8% of Nigeria's total population (National Population Commission, 2013). The State currently comprises 25 Local Government Areas (LGAs) and is made up of three major ethnic groups: the Nupe, Gbagyi, and Hausa.

Sampling Procedure and Sample Size

The study population consists of rural farmers engaged in rice production in Niger State. This study adopted a three-stage sampling technique. Niger State is divided into three Agricultural zones: Zone I, Zone II, and Zone III. In the first stage, one LGA was randomly selected from each zone, for a total of 3 LGAs. In the second stage, three (3) villages were randomly selected from each selected LGA, for a total of 9 villages. In the third stage, respondents were proportionately selected using the Yamane formula based on each village's sample frame, obtained from the Niger State Agricultural and Mechanisation Development Authority (NAMDA). Thus, this study selected a total of 238 registered rice crop farmers as respondents. The Yamane formula was used to determine the appropriate sample size from the identified population of rice farmers. The formula is expressed as:

$$n = \frac{N}{1 + N(e^2)}$$

where *n* is the required sample size, *N* is the population size and *e* is the level of precision.

Method of Data Collection

This study used primary data. The data were collected through a structured questionnaire complemented with an interview schedule. Trained enumerators assisted the researcher during data collection. The collected data were analysed using descriptive and multiple regression analyses. The level of farmers' participation in alternative extension approaches was measured using 21 questions to generate responses from the respondents; the following decisions were derived, as used by Gow *et al.* (2020), for smallholder rice farmers who scored between

0 – 4 = low

5 – 9 = Moderate

10 – 14 = High

These cut-offs transformed the continuous participation scores into meaningful ordinal categories reflecting increasing levels of engagement in alternative extension approaches. This categorisation enabled the study to compare farmers by the intensity of their participation and was used in subsequent descriptive and inferential analyses.

Log-linear regression model

Log-linear regression analysis was used to assess the effect of participation in alternative extension approaches on smallholder rice farmers' output. The generic model adopted for this study is specified in implicit form as

$$Y_j = f(X_{1i}, X_{2i}, X_{3i}, X_{4i}, X_{5i}, X_{6i}, X_{7i}, X_{8i}, X_{9i}, X_{10i}, X_{13i}) \tag{1}$$

The explicit form is in equation 2

Log-linear regression model

$$Y = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \dots + \beta_{13} \ln X_{13} + e \tag{5}$$

Y = Rice farmers’ output measured in kilogram

X₁ = Frequency of contact from the AEA (Number);

X₂ = Numbers of alternative extension methods used (numbers);

X₃ = Duration of participation (number of days);

X₄ = Access to extension materials (Dummy);

X₅ = Exposure to demonstration plots (dummy);

X₆ = Peer to peer learning participation (dummy);

X₇ = Use of WhatsApp and social media for extension (dummy);

X₈ = Timeliness of information received (days from request to delivery);

X₉ = Age (years);

X₁₀ = Education (years);

X₁₁ = Household size (number of persons);

X₁₂ = Farming experience (years); and

X₁₃ = Membership of cooperative (dummy).

ei = Error term

RESULTS AND DISCUSSION

Participation in alternative extension approaches by the respondents

Table 1 presents the distribution of respondents by participation in various Alternative Extension Approaches, categorised into Public Extension, which includes outgrower contract scheme, cooperative partnership, demonstrative trials, advisory technical services, market linkages, and fee-for-service. Public- Private Extension, which includes: rice output aggregation, rice output bundling, input-output linkages, joint training workshops, agricultural finance, agricultural insurance schemes, and participatory research. Finally, Digital Extension, which also includes: mobile SMS using USSD codes, voice messages through call centres, mobile apps, social

platforms, interactive audio response, interactive video response, digital finance platforms and online trainings/webinars.

Public extension approaches

Table 1 shows that most respondents (98.7%) participated in the outgrowers’ contract scheme, indicating that they are tied to structured value chains that provide high-quality inputs and guaranteed buy-back arrangements, which can stabilise income and reduce post-harvest losses. A large proportion of respondents (90.3%) also participated in demonstrative trials, suggesting strong exposure to practical, field-based learning methods. Participation in advisory technical services was also high, with a substantial proportion (80.7%) of respondents benefiting from technical guidance. Approximately 88.2% participated in market linkage initiatives, while high engagement in fee-for-service (89.9%) is significant; it indicates that respondents are willing to pay for extension if they perceive value, a shift away from the traditional free government service model.

These findings indicate a shift toward market-oriented and demand-driven extension systems, which have been associated with improved commercialisation and income outcomes in Nigerian rice production systems (Ragasa and Chapoto, 2017). However, participation in cooperative partnerships was with more than half (52.5%) of the respondents involved, which indicates that not all the respondents are fully engaged in cooperative-based public extension partnerships, potentially limiting collective bargaining benefits.

Public-private extension approaches

Table 1 also shows that 98.7% of respondents participated in rice output aggregation, indicating widespread involvement in collective marketing arrangements facilitated by both public and private actors. Participation in rice output bundling showed that most respondents (73.5%) participated, suggesting effective coordination of produce for storage, processing, or marketing. Aggregation and bundling allow smallholders to behave like large-scale commercial entities, attracting better prices from industrial millers. More than four-fifths (86.1%) participated in input–output linkage programmes, which integrate access to inputs with guaranteed output markets. Joint capacity-building initiatives were also prominent, as 87.0% of respondents participated in joint training workshops.

In addition, the majority (87.0%) engaged in participatory research activities. These participatory approaches enhance farmers’ skills, encourage innovation, and promote the adoption of context-specific technologies. Access to financial risk management tools was equally notable. Most respondents (86.1%) participated in agricultural finance schemes, while 86.6% engaged in agricultural insurance schemes. These institutional arrangements reduce financial vulnerability and encourage investment in improved rice production technologies, thereby supporting income

growth (World Bank, 2021). According to Adebayo *et al.* (2022), Public-private partnerships in extension are increasingly effective in Nigeria, specifically in de-risking the rice value chain through integrated insurance and finance packages.

Digital extension approaches

Participation in digital extension approaches, as shown in Table 1, was remarkably high, reflecting increased integration of information and communication technology into agricultural advisory systems. Most (97.5%) respondents accessed extension information through mobile SMS using USSD codes, highlighting the effectiveness of low-cost, non-internet-based digital tools among rural rice farmers. A large proportion of respondents (91.2%) participated in interactive audio response programmes via radio, while the majority (87.8%) accessed interactive video response via television. These platforms remain highly relevant in Nigeria due to their wide reach and ability to deliver timely production and market information (Aker *et al.*, 2021).

Furthermore, 85.3% used mobile applications such as AgroMail and Esoko, while most of the respondents (84.0%) relied on social media platforms for agricultural information. These tools facilitate real-time interaction, peer learning, and access to diverse information sources. Most respondents (86.1%) used digital finance platforms, and 87.4% participated in online trainings and webinars, indicating growing digital literacy and acceptance of virtual learning environments among rice farmers. Participation in voice messages through call centres was relatively lower, though still notable, with most (63.9%) of respondents using this channel. This suggests that while voice-based services are useful, farmers may prefer more interactive or multimedia-based digital extension tools.

Level of participation in alternative extension approaches

The Likert-type rating scale results on the frequency and level of participation in alternative extension approaches, as presented in Table 2, showed a generally high level of perception among respondents in the study area.

Table 1: Distribution of respondents based on participation in alternative extension approaches (n=238)

Variables	Frequency*	Percentage
Public extension		
Out-growers Contract Scheme	235	98.7
Cooperative Partnership	125	52.5
Demonstrative Trials	215	90.3
Advisory Technical Services	192	80.7
Market Linkages	210	88.2
Fee for Service	214	89.9
Public-private extension		
Rice Output Aggregation	235	98.7
Rice Output Bundling	175	73.5
Input Output Linkages	205	86.1
Joint Training Workshop	207	87.0
Agricultural Finance Scheme	205	86.1
Agricultural Insurance Scheme	206	86.6
Participatory Research	207	87.0
Digital extension		
Mobile SMS using USSD Codes	232	97.5
Voice Messages Through Call Centers	152	63.9
Mobile Apps Like Agro Mail, Esoko	203	85.3
Social Platforms	200	84.0
Interactive Audio Response via Radio	217	91.2
Interactive Video Response via Tv	209	87.8
Digital Finance Platforms	205	86.1
Online Trainings/Webinars	208	87.4

Source: Field Survey,2025

***Multiple Responses were recorded**

Level of participation in public extension approaches

The results showed that the out-growers’ contract scheme ranked first, with the majority (95.8%) of respondents exhibiting a high level of participation ($\bar{X}$ = 2.96). This suggests that the relationship between the farmer and the private firm is the most influential driver of production. This intensity ensures that farmers follow strict agronomic protocols, which minimises yield gaps. Demonstration trials ranked second, with the majority (83.2%) participating at a high level ($\bar{X}$ = 2.77). This reflects the effectiveness of hands-on, experiential learning in encouraging adoption of improved rice technologies. Market linkages also recorded a high level of participation, ranking third, as most (75.2%) respondents were highly involved (2.72). Strong market connections enable farmers to commercialise output efficiently, improving income outcomes

.Fee-for-service extension ranked fourth = 2.34), with most (60.5%) participating at a moderate level. This suggests growing acceptance of demand-driven extension services, although cost considerations may limit full participation. Advisory and technical services ranked fifth ($\bar{X}$ = 2.20), dominated by most (66.4%) moderate participation. This suggests that while advisory services remain important, they may be less intensive than contract-based and market-oriented approaches. Cooperative partnership ranked sixth, with the majority (87.8%) participating at a moderate level ($\bar{X}$ = 2.05). This implies that cooperative involvement is widespread but often limited to routine activities rather than intensive engagement.

Level of participation in public-private extension approaches

Table 2 shows that Rice output aggregation ranked first, with the majority (96.2%) of respondents reporting a high level of participation ($\bar{X}$ = 2.96). This high intensity of aggregation confirms that farmers rely heavily on collective selling to maximise profit. This reduces the power of middlemen who typically exploit individual smallholders. Input–output linkages ($\bar{X}$ = 2.80), ranked second, are dominated by the majority (92.4%); these linkages integrate access to quality inputs with assured output markets, reducing production and marketing risks. The agricultural finance scheme ($\bar{X}$ = 2.71) ranked third, with the majority (75.6%) participating at a high level to access finance through public–private mechanisms, enabling farmers to invest in yield-enhancing technologies promoted through extension services.

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Participatory research ranked fourth (2.64), with most (66.4%) respondents participating at a high level, indicating active farmer involvement in technology testing and adaptation, which enhances relevance and adoption. Agricultural insurance schemes ranked fifth ($\bar{X}$ =2.34), with most (59.7%) reporting a moderate level, suggesting growing awareness of risk management

tools, though full uptake remains limited. Joint training workshops ranked sixth ($\bar{X} = 2.21$), characterised by most (74.8%) moderate level of participation, indicating regular but not intensive engagement and rice output bundling ranked seventh ($\bar{X} = 2.04$), with the majority (92.4%) participating at a moderate level, suggesting that bundling activities are common but not deeply integrated into farmers' production systems. According to Ragasa *et al.* (2020), Joint ventures in output aggregation increased the net profit margin of smallholder rice farmers by 18-22% due to improved quality control and bulk transport savings.

Level of participation in digital extension approaches

The table shows that Mobile SMS ranked first (2.92), with the majority (92.0%) of respondents. This demonstrates the effectiveness of low-cost, non-internet-based digital tools in reaching rural rice farmers and ensures that farmers receive timely alerts about pests or weather, which is crucial for preventing yield loss. Mobile applications such as AgroMall and Esoko ranked second ($\bar{X} = 2.81$), with the majority (81.5%) participating at a high level, suggesting growing acceptance of app-based advisory and market information services. Interactive audio response via radio ranked third ($\bar{X} = 2.72$), with the majority (75.6%) participating at a high level, showing that radio remains a critical medium for agricultural information dissemination in Nigeria due to its accessibility.

Participation in digital finance platforms ranked fourth ($\bar{X} = 2.66$), with the majority (67.2%) participating at a high level, indicating increasing integration of digital financial services into rice production systems. Online trainings and webinars ranked fifth ($\bar{X} = 2.38$), with more than half (55.0%) of respondents, reflecting moderate digital capacity constraints among farmers. Interactive video response via television ranked sixth ($\bar{X} = 2.38$). Social media platforms ranked seventh ($\bar{X} = 2.21$), with most respondents (71.0%) indicating moderate use, suggesting social media is supplementary rather than primary for extension delivery. Voice messages through call centres ranked eighth ($\bar{X} = 2.07$), with most (84.5%) participating at a moderate level, suggesting lower preference than more interactive digital tools. This is similar to Arouna *et al.* (2021), who confirmed that the intensity of digital tool usage, specifically USSD-based advice, is significantly linked to lower chemical residue levels and higher grain quality in rice farming.

Table 2: Distribution of respondents based on level of participation in alternative extension approaches (n=238)

Variables	L	M	H	WS	WM	RE	RA
Public Extension							
Out-growers Contract Scheme	0(0.0)	10(4.2)	228(95.8)	704	2.96	High	1 st
Demonstration Trials	14(5.9)	26(10.9)	198(83.2)	660	2.77	High	2 nd
Market Linkages	8(3.4)	51(21.4)	179(75.2)	647	2.72	High	3 rd
Fee for Service	7(2.9)	144(60.5)	87(36.6)	556	2.34	High	4 th
Advisory/Technical Services	16(6.7)	158(66.4)	64(26.9)	524	2.20	High	5 th
Cooperative Partnership	8(3.4)	209(87.8)	21(8.8)	489	2.05	High	6 th
Public-Private Extension							
Rice Output Aggregation	0(0.0)	9(3.8)	229(96.2)	705	2.96	High	1 st
Input-Output Linkages	10(4.2)	220(92.4)	14(5.9)	667	2.80	High	2 nd
Agricultural Finance Scheme	11(4.6)	47(19.7)	180(75.6)	645	2.71	High	3 rd
Participatory Research	6(2.5)	74(31.1)	158(66.4)	628	2.64	High	4 th
Agricultural Insurance Scheme	7(2.9)	142(59.7)	89(37.4)	558	2.34	High	5 th
Joint Training Workshop	5(2.1)	178(74.8)	55(23.1)	526	2.21	High	6 th
Rice Output Bundling	4(1.7)	220(92.4)	14(5.9)	486	2.04	High	7 th
Digital Extension							
Mobile SMS Using USSD Codes	1(0.4)	18(7.6)	219(92.0)	694	2.92	High	1 st
Mobile Apps like Agro Mall, Esoko,.	1(0.4)	43(18.1)	194(81.5)	669	2.81	High	2 nd
Interactive Audio Response Via Radio	8(3.4)	50(21.0)	180(75.6)	648	2.72	High	3 rd
Digital Finance Platforms	4(1.7)	74(31.1)	160(67.2)	632	2.66	High	4 th
Online Trainings/Webinars	8(3.4)	131(55.0)	99(41.6)	567	2.38	High	5 th
Interactive Video Response Via TV	2(0.8)	144(60.5)	92(38.7)	566	2.38	High	6 th
Social Platforms	10(4.2)	169(71.0)	59(24.8)	525	2.21	High	7 th
Voice Messages Through Call Centers	10(4.2)	201(84.5)	27(11.3)	493	2.07	High	8 th

Source: Field Survey,2025

Decision rule: Weighted Mean ≥ 2.00 = High Participation; Weighted Mean < 2.00 = Low/Moderate Participation, WS = Weighted Sum, WM = Weighted Mean, RE = Remark, RA = Rank, L = Low, M = Moderate and H = High

Regression estimate of the effects of participation in alternative extension approaches on the output of the respondents

Table 3 presents the results of a log-linear regression conducted to determine the effect of participation in alternative extension approaches on rice farmers’ output. The coefficient of determination (R-squared) was 0.5753, indicating that the explanatory variables explained about 57.5% of the variation in rice output. The adjusted R-squared (0.5332) further confirms the model’s fit after adjusting for the number of predictors. At the same time, the F-statistic of 16.54 was statistically significant at $p<0.01$, confirming that the independent variables jointly influenced rice output.

The coefficient of duration of participation was positive and statistically significant on rice output (0.0328, $p<0.05$). The result indicated a "learning-by-doing" effect. Farmers who engaged with alternative extension over a longer period mastered the techniques better than newcomers, enhancing cumulative learning, confidence, and consistency in applying recommended agronomic practices and resulting in steadily increasing rice output. Longer exposure allows farmers to internalise innovations such as improved seed selection, nutrient management, and water-use efficiency. At the same time, extension policies should prioritise long-term farmer engagement over short-term interventions. Continuous participation can enhance technology retention and reinforce behavioural change among rice farmers. This aligns with Mwangi and Kariuki (2025), who found that extension benefits are cumulative; long-term participation builds the confidence needed to invest in more expensive, high-yield inputs.

The coefficient of access to extension materials was positive (0.2369, $p<0.01$). The results showed that farmers who regularly accessed manuals, flyers, guides, and digital advisory materials produced more rice. Extension materials serve as reference tools that reinforce training information and improve farmers' application of fertilisers and chemicals. Extension systems should invest in context-specific, farmer-friendly materials, including mobile-based content and visual aids, particularly for rice-growing communities with varying literacy levels. This aligns with Arouna *et al.* (2021), who reported that physical or digital guides reduce field errors, leading to higher technical efficiency and yield.

Table 3: Regression estimates of the effects of participation in alternative extension approaches on rice output (kg). Dependent variable: Rice output (kg)

Variables	Semi – log
Constant	7.1475 (24.03)***
Frequency of contact from AEA	0.0004 (0.08)
Alternative extension methods	-0.02760 (-1.27)
Duration of participation	0.0328 (2.39)**
Access to extension materials	0.2369 (6.07)***
Exposure to demonstration plots	0.1965 (2.26)**
Peer to peer learning participation	-0.1680 (2.34)**
Use of WhatsApp/social media	0.1031 (1.84)*
Timeliness of information	0.0012 (0.18)
Age	0.0063 (1.39)
Education	0.0060 (1.95)*
Household size	0.002 (0.39)
Farming Experience	-0.0066 (-1.77)*
Membership cooperative	0.1937 (1.32)
R ²	0.5753
R ² – adjusted	0.5332
F – ratio	16.54***

Source: Field Survey, 2025

Note: *** implies statistically significant at 1%, ** implies statistically significant at 5%, * implies statistically significant at 10%. Figures in parenthesis

The coefficient of exposure to demonstration plots was positive and statistically significant ($\beta = 0.1965$, $p < 0.05$), indicating a positive association with rice output. Demonstration plots provide experiential learning opportunities that let farmers observe the performance of improved rice varieties and production practices under local conditions. This practical exposure may enhance farmers’ understanding and confidence in applying recommended technologies. The finding is consistent with evidence on the role of practical and technology-based extension in improving rice production outcomes (Arouna *et al.*, 2021).

The coefficient of peer-to-peer learning was negative and statistically significant ($\beta = -0.168$, $p < 0.05$), indicating an inverse association between participation in peer-to-peer learning and rice output. This finding may indicate ineffective knowledge transfer or variability in the quality and relevance of information exchanged through peer networks. Although peer-to-peer learning can facilitate the sharing of practical farming experiences, the negative coefficient suggests that participation in such networks did not translate into higher rice output among farmers in the study area. The finding therefore highlights the need to strengthen the quality, accuracy and relevance of knowledge exchanged through peer learning platforms, particularly through appropriate linkages with trained extension personnel. This result should, however, be interpreted cautiously, as the regression coefficient alone does not establish that misinformation or inaccurate information caused the observed negative association.

The coefficient for WhatsApp and other social media use was positive (0.1031, $p < 0.10$) and statistically significant for rice output. This revealed the growing role of digital extension in facilitating rapid information exchange, peer interaction and timely access to production and market information. Digital social platforms emerge as a significant driver of output, enabling rapid problem-solving that prevents crop loss. Development agencies should integrate social media-based advisory services into extension delivery frameworks to complement conventional methods. Similarly, Kante (2024) found that WhatsApp groups function as real-time extension and significantly reduce the time between a field problem and a technical solution.

The coefficient of education was positive (0.0060, $p < 0.01$) and statistically significant on rice output. This suggests that more educated farmers better comprehend and apply extension messages. Extension programmes should adopt simplified, inclusive communication strategies for less-educated farmers while promoting adult education and capacity-building initiatives. This aligns with Idrisa *et al.* (2021), who reported that education has consistently been linked to higher adoption of improved rice technologies in Nigeria.

The coefficient of farming experience was negative (-0.0066, $p < 0.01$) and statistically significant on rice output. This suggests that more experienced farmers may be less receptive to new extension messages because they rely on traditional practices. This suggests that extension personnel should design targeted sensitisation strategies for more experienced farmers to address resistance to innovation and demonstrate the economic benefits of improved practices. Abdulrahman *et al.* (2020) observed that, in Nigerian rice farming systems, farmer experience sometimes discourages adoption of innovations.

CONCLUSION

The study established that smallholder rice farmers in Niger State recorded a high level of participation in public, public–private and digital alternative extension approaches. Out-growers’ contract schemes, rice output aggregation and mobile SMS-based advisory services were the most utilised extension models among the respondents. The regression results further revealed that duration of participation, access to extension materials, exposure to demonstration plots, use of WhatsApp/social media and education significantly increased rice output, while peer-to-peer learning participation and farming experience negatively influenced output. The study therefore concludes that effective participation in alternative extension approaches contributes positively to improved rice productivity among smallholder farmers through enhanced access to information, practical learning and digital advisory support.

RECOMMENDATIONS

- i. Government agencies, development partners and extension organisations should strengthen digital and demonstration-based extension systems by expanding access to mobile advisory platforms, farmer field schools and context-specific extension materials to enhance rice productivity among smallholder farmers.
- ii. Extension service providers should ensure that peer-to-peer learning activities are professionally supervised and supported with accurate technical information to minimise the spread of misleading practices and improve farmers’ adoption of recommended rice production technologies.

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