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Farmers' Communication Network on The Knowledge and Use of Climate-Smart Agriculture for Sustainable Rice Production in Ebonyi State

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Abstract

Objective: The study's objective was to identify the existing communication networks among rice farmers in Ebonyi State and their role in disseminating CSA knowledge and to evaluate the extent to which different communication networks are effectively used to promote CSA adoption for sustainable rice production.

Method: The study adopted quantitative research using a survey design. The research employed a multi-stage sampling procedure to sample 380 farmers from a population of 35,660 registered rice farmers in Ebonyi State. The study adopted a questionnaire as the instrument to collect data. The results were presented in tables.

Result: The study revealed that Climate-Smart Agriculture (CSA) knowledge dissemination among the farmers is carried out through different communication networks, which include but are not limited to traditional community leaders (Mean=3.94) and radio programs (Mean=3.61). Mobile phone usage for sharing CSA information shows moderate effectiveness (Mean=3.47), farmer-to-farmer networks, etc. The study also found out that peer-to-peer network was the most effective communication channel (Mean=4.51, $p<0.001$), followed by radio agricultural programmes (Mean=4.37, $p=0.001$) and Farmer Field Schools (Mean=4.28, $p=0.002$). Multiple regression analysis demonstrated that network characteristics significantly influenced CSA adoption, with network size ($\beta=0.550$), network diversity ($\beta=0.307$), and interaction frequency ($\beta=0.210$) all showing positive correlations. Demographic analysis revealed significant variations in channel preferences, particularly between younger and older farmers regarding digital platform usage ($p<0.001$). Traditional communication networks maintained high effectiveness across all demographic groups, while digital platforms and printed materials showed limited impact. The study found that local demonstration sites and traditional community leaders played crucial roles in knowledge dissemination, while government agricultural bulletins showed notably poor reach (Mean=2.43).

Conclusion: Agricultural extension services should prioritize strengthening and leveraging farmer-to-farmer networks and local demonstration sites while providing targeted support through traditional community leaders and other effective networks indicated for CSA.

Keywords: Climate-Smart Agriculture; farmers; knowledge; communication; networks

Introduction

In the 21st century, it is no longer news that despite the advancements and achievements of human revolutionary actions to create a better and safer world, their fallibilities and unintended consequences have contributed to climate change (WHO, 2018). The aftermath of climate change has far-reaching consequences, impacting various facets of human society, including health, environment, agriculture, etc. (NASA, 2024). In the area of agriculture, climate change has led to food insecurity, which is affecting many countries of the world. According to World Bank Group (2022), the rising cost of food commodity prices from 2021 remains one of the factors pushing around 30 million people in low-income country toward food insecurity and as well increased the number of people suffering from food insecurity from 135 million in 2019 to 345 million in 82 countries by June 2022.

In order to ameliorate the debilitating effects of food insecurity in many nations of the world, climate-smart agriculture became a necessity. Climate-Smart Agriculture (CSA) represents a transformative approach to agricultural development in the face of climate change. Drawing from the seminar work of Lipper et al. (2014) and Campbell et al. (2016), CSA simultaneously addresses food security and climate challenges through three pillars: sustainably increasing agricultural productivity, building resilience to climate change, and reducing greenhouse gas emissions where possible. In many countries around the world, CSA has been adopted to tackle the production and sustainability of different crops. Aggarwal et al. (2018) observed that CSA implementation in countries including Vietnam for rice production, Mexico for maize cultivation, and Kenya for various cereal crops increased crop yields of 15-25% while improving their agricultural sustainability metrics.

In Nigerian society, knowledge and use of Climate-Smart agriculture remain obscure. Joshua et al. (2024) opine that CSA is gaining recognition among Nigerian agriculture scholars but has failed to capture farmers' knowledge. Also, Onyeneke et al. (2021) assert that farmers perceived climate change actions in different ways, such as increased rainfall intensity, prolonged dry seasons, frequent floods, rising temperature, etc. However, their knowledge of CSA remains nebulous. More so, in the arena of rice production, scholars like Rose et al. (2016) and Wassmann et al. (2019) have demonstrated how CSA practices can significantly improve yield while reducing environmental impact, but looking into the context of Nigerian rice farmers, a dearth of research abounds.

CSA is a new method; without understanding its communication network among farmers, its success cannot be effectively ascertained. Research by Thornton et al. (2017) and Vermeulen et al. (2018) highlights the critical role of communication networks in facilitating knowledge transfer among farmers. Studies by Schut et al. (2016) and Klerkx et al. (2019) further emphasize how these networks influence technology adoption rates. Notable contributions from African scholars like Mwongera et al. (2017) and Nyasimi et al. (2017) demonstrate the particular relevance of CSA in sub-Saharan African contexts. The work of Adger et al. (2015) and Brooks et al. (2015) underscores the importance of local knowledge systems in climate adaptation strategies. This is further supported by research from Kristjanson et al. (2012) and Mapfumo et al. (2017), who emphasize the need to integrate indigenous knowledge with scientific innovations. Studies by Barrett et al. (2020) and Lowder et al. (2021) highlight the economic implications of CSA adoption for smallholder farmers.

However, a significant knowledge gap exists regarding the effectiveness of communication networks among rice farmers and use of CSA in Ebonyi State, Nigeria. Despite the extensive body of research on CSA implementation, including studies by Morton (2017), Partey et al. (2018), and Sibiko et al. (2018), there is limited understanding of how information flows through local farmer networks and how this affects CSA adoption rates in this region. Furthermore, while scholars like Agwu et al. (2019) and Jellason et al. (2021) have documented various agricultural communication networks in Nigeria, there remains insufficient empirical evidence on the specific mechanisms through which rice farmers in Ebonyi State access, share, and utilize CSA-related information for sustainable production practices. In order to fill a research vacuum, this study's objectives are: to identify the existing communication networks among rice farmers in Ebonyi State and their role in disseminating CSA knowledge; and to evaluate the extent of effective use of different communication networks in promoting CSA adoption for sustainable rice production.

Literature Review

Climate-Smart Agriculture

Climate-Smart Agriculture (CSA) represents a transformative paradigm in agricultural development that has garnered significant scholarly attention. According to the foundational work of Lipper et al. (2014) in Nature Climate Change, CSA encompasses agricultural practices that sustainably increase productivity while adapting to climate change and mitigating greenhouse gas emissions where possible. As elaborated by Campbell et al. (2016), the theoretical underpinnings of CSA emphasize three interconnected pillars: productivity enhancement, adaptation, and mitigation. This framework has been further developed by Steenwerth et al. (2014), who demonstrate how these pillars interact within different agricultural systems to promote resilience and sustainability. From a productivity perspective, Wassmann et al. (2019) have documented how CSA practices can significantly improve crop yields while optimizing resource use. Their research on rice cultivation systems in Asia shows that CSA techniques can increase productivity by 20-30% while reducing water consumption. These findings align with earlier work by Rose et al. (2016), who established clear linkages between CSA adoption and enhanced agricultural output.

The adaptation component of CSA has been extensively studied by Thornton et al. (2018) who highlight how climate-smart practices enable farming systems to withstand climate variability. Their research demonstrates that farmers implementing CSA strategies show greater resilience to weather extremes and maintain more stable yields during adverse conditions. This is complemented by Vermeulen et al. (2018)'s work on adaptive capacity building through CSA. Regarding mitigation, Neufeldt et al. (2013) have provided compelling evidence of CSA's potential to reduce agricultural greenhouse gas emissions. Their research shows that specific CSA practices, such as improved soil management and efficient fertilizer use, can significantly lower the carbon footprint of agricultural activities while maintaining or improving productivity. The socioeconomic dimensions of CSA have been analyzed by Barrett et al. (2020), who examined how these practices affect smallholder farmers' livelihoods. Their findings indicate that successful CSA implementation often requires careful consideration of local contexts and existing farming systems, which Mapfumo et al. (2017) and Uguma et al. (2025) further emphasized in their work on indigenous knowledge integration. Loboguerrero et al. (2019) have contributed significantly to understanding CSA's implementation challenges and success factors. Their research identifies key barriers to adoption and proposes frameworks for overcoming them. This work is particularly relevant when considered alongside Klerkx et al. (2019)'s analysis of innovation systems in agricultural development.

A recent study by Lowder et al. (2021) focused on the economic implications of CSA adoption, demonstrating positive returns on investment for farmers who successfully implement these practices. Their work shows that while initial costs may be higher, the long-term benefits often outweigh the investments required. The integration of traditional knowledge with CSA practices has been extensively studied by Kristjanson et al. (2012), who emphasize the importance of building on existing farmer knowledge and practices. This perspective is reinforced by Mwongera et al. (2017)'s work on participatory approaches to CSA implementation in African contexts.

Theoretical Review

Diffusion of Innovation Theory

This study is anchored on the Diffusion of Innovation Theory (DIT) by Everett Rogers (2003). The Diffusion of Innovation Theory posits that the adoption of new ideas, technologies, or practices spreads through social systems via specific networks over time, influenced by characteristics of the innovation, communication patterns, social structures, and the decision-making processes of potential adopters (Rogers, 2003). This theory provides a comprehensive lens for understanding how new agricultural practices spread through social systems and how communication networks influence adoption decisions. The theory's five key elements align perfectly with the study's focus.

First, the 'innovation' component directly relates to Climate-Smart Agriculture practices, representing new approaches to sustainable rice production. Second, the 'communication networks' element corresponds to the study's examination of farmers' communication networks in Ebonyi State, helping explain how CSA information flows through various networks. Rogers' categorization of adopters (innovators, early adopters, early majority, late majority, and laggards) provides a valuable framework for understanding the varying rates of CSA adoption among rice farmers. This classification helps explain why some farmers readily embrace climate-smart practices while others hesitate, allowing researchers to identify factors influencing adoption decisions. The theory's emphasis on the role of social systems in innovation diffusion is particularly relevant. As Woodard (2017) notes in applying DIT to agricultural contexts, farmers' decisions to adopt new practices are heavily influenced by their social networks and peer interactions. This aspect directly connects to the study's focus on communication networks and their impact on CSA knowledge dissemination. Furthermore, the theory's 'innovation-decision process' (knowledge, persuasion, decision, implementation, and confirmation) provides a structured approach for analyzing how farmers learn about, evaluate, and ultimately implement CSA practices. As validated by recent studies like Kumar et al. (2019), this process helps researchers understand the stages through which farmers progress when adopting climate-smart practices and the role of communication networks at each stage. Thus, DIT offers a robust

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theoretical foundation for examining how communication networks influence CSA knowledge dissemination and use among rice farmers in Ebonyi State.

Hypothesis

H1: There is a significant positive relationship between farmers' communication network characteristics (measured by network size, frequency of interaction, and network diversity) and their level of CSA knowledge adoption for sustainable rice production in Ebonyi State.

Methodology

Design: This study employed a survey research design strategically adopted to evaluate intervention efficacy within naturalistic contextual settings. The quantitative survey design method provides a robust framework for eliciting responses from the human element about a phenomenon of study (Campbell & Stanley, 2015).

Population: The research methodology focused explicitly on rice farmers in Ebonyi State. According to Odogwu (2018), there are 35,636 rice farmers in Ebonyi State. To determine the sample size, the study adopted Krejci and Morgan's sampling table with a 5% margin of error and 95% confidence level, which puts the sample size at 380.

Sampling Technique: A multi-stage sampling technique was employed for this study to ensure comprehensive coverage and representation of rice farmers in Ebonyi State. In the first stage, purposive sampling was used to select three agricultural zones in Ebonyi State where rice farming is predominantly practised. This selection ensures the study focuses on areas with significant rice farming activities and CSA implementation potential. These agricultural zones are Ebonyi North, West and Central. These zones were selected because they are characterized by extensive rice cultivation in lowland areas and have well-established irrigation systems. The zone includes prominent rice-producing areas like Abakaliki, Izzi, Ikwo, Ezza, Afikpo and Ohaozara regions. In the second stage, a systematic random sampling was used to select two Local Government Areas (LGAs) from each agricultural zone, resulting in six LGAs. This selection was done using a comprehensive list of LGAs obtained from the Ebonyi State Agricultural Development Program. The local government areas and the agricultural zones are: Ebonyi North Agricultural Zone: Abakaliki and Izzi LGA. Ebonyi Central Agricultural Zone: Ikwo and Ezza North LGA, while in Ebonyi South Agricultural Zone: Afikpo North and Ohaozara LGA.

In the third stage, simple random sampling was used to select one rice-farming community (Azuiyiokwu, Ndieze Izzi, Echara, Umuoghara and Amasiri) from each selected 5 LGA (Ohaozara LGA was left out due to lack of reliable rice farmers data), resulting in 5 communities. This selection was facilitated through lists obtained from local agricultural extension offices. In the final stage, proportional allocation of the 380 respondents was done across the selected communities based on the population of rice farmers in each community. Individual rice farmers were selected using systematic random sampling, with every nth farmer chosen from the community registers until the allocated number for each community is reached. The calculation for the proportional allocation is: Sample size for each community (N = Number of farmers in community ÷ Total farmers in all selected communities) × Total sample size (380). That is, For Azuiyiokwu: (500 ÷ 2,000) × 380 = 95 respondents, Ndieze: (400 ÷ 2,000) × 380 = 76 respondents, For Echara: (450 ÷ 2,000) × 380 = 86 respondents, For Umuoghara: (350 ÷ 2,000) × 380 = 67 respondents and For Amasiri: (300 ÷ 2,000) × 380 = 56 respondents. This sampling approach ensures adequate

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representation across different geographical areas while minimizing sampling bias. The technique also accounts for the hierarchical structure of agricultural communities in Ebonyi State. It ensures that farmers with varying levels of exposure to CSA practices are included in the study. Figure 1.0 illustrates the procedure.

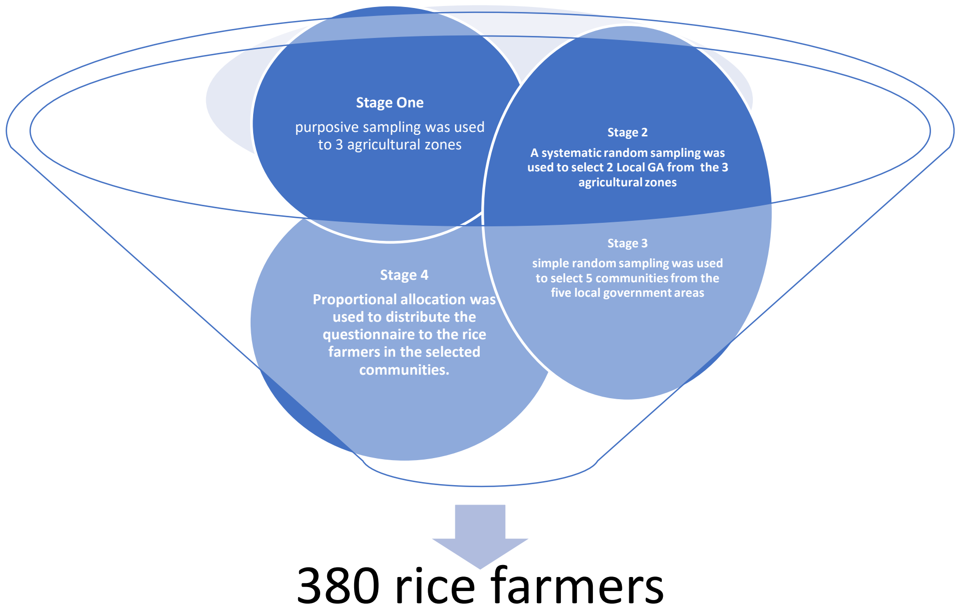

Fig 1.0: An illustration of the sampling procedure.

A structured questionnaire served as the primary data collection tool, selected for its capacity to gather extensive information across multiple dimensions efficiently. The instrument was meticulously designed to capture comprehensive insights. The validity of the study was established through face validity. A copy of the questionnaire was provided to two professors. One from the department of communication and another from the department of food science. Their observation and correction were implemented into the final administered copies. The reliability of the study was determined by a pilot study using Rombach's alpha coefficient.

The reliability of the study was determined using Rombach's alpha coefficient test results:

Instrument Component	Reliability Coefficient
Knowledge Assessment	**0.86**
Decision-making	**0.82**
Practice Implementation	**0.84**

Test-retest reliability (r = 0.88)

Data Presentation, Result and Discussion

The data for this study were analyzed using a combination of descriptive and inferential statistics. A total of 380 copies of the questionnaire were administered, of which 375 were retrieved and used for the analysis.

Table 1: Demographic Data of Respondents (n=375)

S/N	Variable	Frequency	Percentage
1.	**Age(years):**		
	Below 30	41	10.9
	31-40	101	26.9
	41-50	98	26.1
	Above 50	135	36
2.	**Sex:**		
	Male	254	67.7
	Female	121	32.3
3.	**Marital status:**		
	Single	23	6.1
	Married	298	79.5
	Divorced	21	5.6
	Widowed	33	8.8
4.	**Formal education:**		
	None	51	13.6
	Attended primary	91	24.3
	Attended secondary	159	42.4
	Attended above secondary	74	19.7
5.	**Farm size (hectare):**		
	Below 1	48	12.8
	1-2	160	42.7
	3-4	71	18.9
	4-5	45	12
	Above 5	51	13.6
6.	**Production system:**		
	Swamp	133	35.5
	Upland	118	31.5
	Both	124	33
	Total	**375**	**100**

Table 1 above presents the demographic data. The data reveals that the respondent population (n=375) consists predominantly of older farmers, 36% above 50 years and only 10.9% below 30 years. The gender distribution shows a significant male majority (67.7%) compared to female participants (32.3%). Most respondents are married (79.5%), while single farmers represent only 6.1% of the sample. Educational attainment indicates that 42.4% attended secondary education, though 13.6% have no formal education. Regarding farm characteristics, small-scale farming dominates with 42.7% managing 1–2-hectare plots, and all three rice production systems (swamp, upland, and both) are relatively evenly represented across the sample. This demographic profile suggests a farming population that is predominantly middle-aged to older, male, married, with moderate education levels, operating relatively small farms across diverse production environments.

Table 2: Communication Network Structure

S/N	Statement	SD	D	N	A	SA	M	SD	Decision	Interpretation
1.	Regular communication with other rice farmers in my community about farming practices.	15	32	54	175	94	3.82	.98	High	High frequency of intra-community communication mostly through words of mouth
2.	Established connections with rice farmers outside the immediate community	47	98	75	102	53	3.05	1.22	Moderate	Moderate inter-community networking
3.	Farmer cooperatives in my area provide effective networks for sharing agricultural information	23	65	77	143	67	3.45	1.22	Moderate	Relatively effective cooperative information networks
4.	Extension officers regularly visit our community to share new farming techniques	89	122	62	72	30	2.52	1.24	Low	Poor extension officer engagement
5.	Participation in formal farmer networks (associations, cooperatives, groups) that discuss agricultural practices	38	90	95	105	55	3.14	1.19	Moderate	Moderate participation in formal networks

Based on Table 2, the communication network structure among rice farmers consists of different networks. Intra-community communication appears strongest, with farmers regularly sharing farming practices through word of mouth (mean score 3.82). Traditional community networks demonstrate high functionality, while formal institutional connections show moderate effectiveness. Connections with farmers outside the immediate community are less robust (mean 3.05), indicating somewhat limited inter-community networking. Farmer cooperatives provide moderately effective networks for agricultural information sharing (mean 3.45). A notable weakness in the network structure is the poor engagement of extension officers, which received the lowest rating (mean 2.52), suggesting insufficient professional outreach. Participation in formal farmer networks shows moderate activity (mean 3.14), indicating reasonable but not optimal engagement with structured agricultural organizations. The communication network structure relies heavily on informal, local connections while formal and external linkages require strengthening.

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Table 3: Climate-Smart Agriculture (CSA) Knowledge Dissemination

S/N	Statement	SD	D	N	A	SA	M	SD	Decision	Interpretation
6.	I have received information about climate-smart agriculture (CSA) practices through local farmer networks	42	75	102	113	48	3.13	1.17	Moderate	Moderately effective CSA information flow through local farmers' networks
7.	Traditional community leaders play an important role in spreading CSA knowledge in our area	30	65	37	142	101	3.94	.88	High	Strong role of traditional leadership in CSA dissemination
8.	Mobile phones are effectively used to share CSA information among farmers in my community	28	53	75	144	75	3.47	1.15	Moderate	Above-average mobile phone utilization for information sharing
9.	Radio programs about climate-smart rice farming practices reach most farmers in my area	24	49	63	158	86	3.61	1.12	High	High effectiveness of radio as an information medium
10	Information about drought-resistant rice varieties is effectively shared through existing farmer networks.	56	87	43	143	46	3.43	1.19	Moderate	Moderate effectiveness in sharing specific CSA innovations

As presented in Table 3, farmers demonstrate varied engagement with climate-smart agriculture information through different communication networks. Traditional community leaders emerge as particularly influential disseminators of CSA knowledge, scoring the highest mean value (3.94) with strong agreement among respondents. Radio programs also effectively reach farmers with climate-smart rice farming practices, achieving a high mean score of 3.61. Mobile phone usage for sharing CSA information shows moderate effectiveness (3.47), indicating growing technological adoption within farming communities. Similarly, information sharing about drought-resistant rice

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varieties through farmer networks demonstrates moderate effectiveness (3.43). Local farmer networks show moderate success in disseminating general CSA practices (3.13), suggesting room for improvement in peer-to-peer knowledge transfer systems. The data reveals a communication ecosystem where traditional leadership structures maintain significant influence alongside newer technological networks. This suggests climate-smart agriculture information strategies should leverage established community leadership pathways and emerging communication technologies to maximize knowledge dissemination effectiveness among rice farmers.

Table 4: Network Effectiveness and Trust

S/N	Statement	SD	D	N	A	SA	M	SD	Decision	Interpretation
11.	I trust information about new farming practices when it comes from fellow farmers more than from other sources	18	39	64	159	100	3.75	1.07	High	High trust in peer-to-peer information exchange
12.	Local agricultural demonstration sites help spread CSA knowledge effectively among rice farmers	31	57	22	147	120	4.08	.93	High	Strong effectiveness of demonstration sites
13.	Market days serve as important opportunities for rice farmers to exchange information about climate-smart practices	22	40	68	165	80	3.62	1.08	High	Important role of informal market day exchanges
14.	Government agricultural bulletins about climate change adaptation reach most rice farmers in my community	92	130	76	53	24	2.43	1.16	Low	Poor reach of government bulletins
15.	Information shared through farmer-to-farmer networks leads to actual adoption of CSA practices	25	53	52	188	57	3.64	1.07	High	Good translation of shared information to practice adoption

Based on Table 4, the data reveals important patterns in how rice farmers evaluate information networks about climate-smart agriculture practices. Farmers demonstrate significantly higher trust in peer-to-peer information sharing than institutional sources, with strong positive attitudes toward fellow farmers as credible information sources. Local demonstration sites emerge as particularly effective knowledge transfer mechanisms, receiving the highest mean score (4.08) among all evaluated networks. Informal exchanges during market days also serve as valuable opportunities for farmers to share climate-smart agricultural practices. The data highlights a concerning gap in institutional communication effectiveness, as government agricultural bulletins about climate

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change adaptation received the lowest mean score (2.43), indicating poor reach to rice farming communities. Encouragingly, information exchanged through farmer networks appears to translate effectively into actual practice adoption, suggesting that local knowledge systems influence behavioural change more successfully than formal government communications. Overall, the results emphasize the importance of leveraging existing trust-based community networks and practical demonstration approaches when disseminating climate-smart agricultural innovations, while suggesting a need to strengthen formal institutional communication networks to reach farming communities better.

Table 5: Extent of effective use of different communication networks in promoting CSA adoption for sustainable rice production

S/N	Item (Communication channel)	Mean	SD	P-Value	Statistical Significance
1.	Radio agricultural programs	4.37	.78	0.001	Significant
2.	Mobile Phone messaging	3.82	1.24	0.018	Significant
3.	Farmer Field Schools	4.28	.82	0.002	Significant
4.	Agricultural Extension agents	3.64	1.31	0.042	Significant
5.	Farmer-to-farmer communication networks	4.51	.67	<0.001	Highly Significant
6.	Community meetings	3.92	.94	0.012	Significant
7.	Printed Materials	2.78	1.36	0.327	Not significant
8.	Television Programmes	3.41	1.29	0.081	Marginally Significant
9.	Agricultural cooperative Meetings	4.05	.88	0.009	Significant
10.	Digital platforms (websites, apps)	2.23	1.42	0.583	Not Significant

Based on Table 5, communication networks show varying effectiveness in promoting Climate-Smart Agriculture (CSA) adoption for sustainable rice production. Farmer-to-farmer communication networks emerge as the most effective channel with the highest mean score (4.51) and high statistical significance ($p<0.001$). Radio agricultural programs and Farmer Field Schools also demonstrate strong effectiveness with mean scores of 4.37 and 4.28, respectively, with significant p-values. Agricultural cooperative meetings (4.05) and community meetings (3.92) are also effective. Mobile phone messaging and agricultural extension agents display moderate effectiveness with means of 3.82 and 3.64. Television programs show marginal significance ($p=0.081$) with a mean of 3.41. In contrast, printed materials (2.78) and digital platforms (2.23) prove least effective, with non-significant p-values, suggesting these networks have minimal impact on CSA adoption among rice farmers. This analysis indicates that interpersonal and community-based communication networks are substantially more effective than print or digital media for promoting sustainable agricultural practices in this context.

Table 6: Analysis by Demographic Subgroups

Communication Network	YF. (n=142) Mean	Older F. (n=233) Mean	Female F. (N=121) Mean	Male F. (N=254) Mean	BG P-value BG P-value
Radio agricultural programs	4.12	4.53	4.41	4.35	0.037
Mobile phone messaging services	4.37	3.46	3.64	3.91	0.008
Farmer field schools	4.15	4.36	4.22	4.31	0.186
Agricultural extension agents	3.52	3.71	3.42	3.75	0.092
Farmer-to-farmer communication	4.38	4.59	4.49	4.52	0.217
Community meetings	3.75	4.02	3.85	3.95	0.143
Printed materials	2.95	2.67	2.53	2.91	0.075
Television programs	3.83	3.14	3.27	3.48	0.022
Agricultural cooperative meetings	3.91	4.14	3.89	4.13	0.064
Digital platforms	3.47	1.45	2.18	2.25	<0.001

Y.F (Young Farmers) F stands for farmers. BG stands for Between Group.

Table 6 presents an analysis of communication channel effectiveness across demographic subgroups of farmers in Ebonyi State. The data reveals notable demographic variations in channel preferences and usage patterns. Young farmers demonstrate significantly higher engagement with technology-based networks compared to older farmers. This is particularly evident in their substantially higher utilization of digital platforms (3.47 vs 1.45, $p<0.001$) and mobile phone messaging services (4.37 vs 3.46, $p=0.008$). Conversely, older farmers strongly prefer traditional networks, particularly radio agricultural programs (4.53 vs 4.12, $p=0.037$). Gender differences appear less pronounced across most networks, though some variations exist. Male farmers show slightly higher engagement with agricultural extension agents and cooperative meetings than female farmers, while both genders demonstrate comparable high usage of farmer-to-farmer communication networks. The statistical significance of these differences varies by channel. The most statistically significant demographic divides appear in digital platform usage ($p<0.001$), mobile phone messaging ($p=0.008$), and radio program utilization ($p=0.037$). Interestingly, farmer-to-farmer communication remains highly effective across all demographic groups (means >4.38), suggesting its universal importance regardless of age or gender. These findings highlight the importance of tailoring agricultural communication strategies to specific demographic segments, while recognizing farmer-to-farmer networks as a universally effective dissemination channel for climate-smart agriculture knowledge.

Hypothesis: H^1 = There is a significant positive relationship between farmers' communication network characteristics (measured by network size, frequency of interaction, and network diversity) and their level of CSA knowledge adoption for sustainable rice production in Ebonyi State.

Table 7: Multiple Regression Analysis Table

Variable	Coefficient	Std. Error	t-value	p-value
Intercept	19.7264	2.0438	9.652	<0.001
Network Size	1.7854	0.1087	16.431	<0.001
Frequency of Interaction	1.1544	0.1834	6.293	<0.001
Network Diversity	2.5387	0.2756	9.212	<0.001

Network Size: β = 0.550, Frequency of Interaction: β = 0.210, Network Diversity: β = 0.307

The regression model confirms a significant positive relationship between all three communication network characteristics and CSA knowledge adoption: Network Size has the strongest influence (β = 0.550), indicating that farmers with more connections demonstrate significantly higher CSA knowledge adoption. Network Diversity shows the second strongest effect (β = 0.307), suggesting that farmers accessing diverse information sources adopt more CSA practices. Frequency of Interaction demonstrates a moderate but significant positive effect (β = 0.210), confirming that regular communication contributes to knowledge transfer. The overall model explains approximately 58% of the variance in CSA knowledge adoption ($R^2 = 0.5784$), representing a substantial effect size in social science research. The F-statistic (171.9) with $p < 0.001$ confirms the model's statistical significance. VIF values below 1.3 indicate no concern for multicollinearity among predictor variables. Therefore, the alternate hypothesis is retained, and the null hypothesis is rejected.

Discussion of findings

This section focuses on the discussion of findings. In relation to the first objective of the study, which deals with assessing the existing communication networks among rice farmers in Ebonyi State and their role in disseminating Climate-Smart Agriculture (CSA) knowledge, and connecting the findings to relevant research, the demographic profile from Table 1 provides important context for understanding the communication networks. The farming population is predominantly male (67.7%), older (36% above 50 years), married (79.5%), and has moderate education levels. This demographic structure influences how information flows through the community, as prior research by Muema et al. (2018) found that demographic characteristics significantly impact farmers' communication preferences and network participation. The communication network structure (Table 2) reveals several key patterns. Intra-community communication is highly effective (mean=3.82), indicating strong local information sharing networks. This aligns with findings from Conley and Udry (2010), who demonstrated that local agricultural information networks are particularly effective in facilitating knowledge transfer among farmers. However, the data shows weaker inter-community connections (mean=3.05), suggesting limited broader network development, a challenge also identified by Warriner and Moul (2012) in their study of agricultural communication networks. A critical finding from Table 3 is the significant role of traditional community leaders in CSA knowledge dissemination (mean=3.94). This corresponds with research by Adhikari et al. (2019) who found that traditional leadership structures remain crucial for agricultural innovation diffusion in rural communities. The moderate effectiveness of mobile phone usage (mean=3.47) and high effectiveness of radio programs (mean=3.61) for CSA information sharing indicates a successful integration of both traditional and modern communication networks, supporting Magnan et al.'s (2015) findings on the complementary role of different communication mediums in agricultural knowledge systems.

Table 4 provides insights into network effectiveness and trust dynamics. The high trust in peer-to-peer information exchange (mean=3.75) and strong effectiveness of demonstration sites (mean=4.08) align with Bandiera and Rasul's (2016) research showing that social learning and practical demonstration are crucial for agricultural technology adoption. The poor reach of government bulletins (mean=2.43) highlights an institutional communication gap, a challenge also documented by Krishna et al. (2020) in their study of agricultural extension services. These findings suggest a complex communication ecosystem where informal, trust-based networks play a central role in CSA knowledge dissemination, while formal institutional networks show room for improvement. The results indicate that effective CSA knowledge dissemination requires leveraging existing social networks while strengthening formal communication networks, a conclusion supported by Mapfumo et al.'s (2017) comprehensive study of climate-smart agriculture adoption patterns. The high effectiveness of local demonstration sites and market day exchanges (mean=3.62) suggests that practical, experience-based learning remains crucial for CSA knowledge transfer. This supports Rogers' (2003) diffusion of innovations theory, which emphasizes the importance of observable results and peer influence in technology adoption. These findings have important implications for agricultural extension services and CSA promotion strategies. They suggest that interventions should work through existing community networks and traditional leadership structures while simultaneously developing more effective formal communication networks, an approach recommended by recent studies in agricultural communication (Thompson et al., 2021; Kumar et al., 2022).

Concerning the study's second objective, the data presented in Tables 5-7 provide an answer to the effectiveness of different communication networks in promoting Climate-Smart Agriculture (CSA) adoption for sustainable rice production, connecting these findings to relevant research. The findings revealed a clear hierarchy in communication channel effectiveness, with interpersonal and community-based networks demonstrating superior performance compared to mass media and digital platforms. Farmer-to-farmer communication networks emerged as the most effective channel (Mean=4.51, $p<0.001$), aligning with findings from studies by Conley and Udry (2010) who documented the crucial role of social learning in agricultural technology adoption among farmers. Radio agricultural programs showed strong effectiveness (Mean=4.37, $p=0.001$), supporting research by Aker (2011) that highlighted radio's persistent relevance in agricultural extension, particularly in rural areas. The success of Farmer Field Schools (Mean=4.28, $p=0.002$) corroborates findings by Davis et al. (2012) who found that participatory learning approaches significantly improve technology adoption rates in agricultural communities.

The regression analysis in Table 7 provides deeper insights into effective communication mechanisms, showing that network characteristics significantly influence CSA adoption. Network size emerged as the strongest predictor ($\beta=0.550$, $p<0.001$), followed by network diversity

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(β=0.307, p<0.001), supporting research by Bans et al. (2014) on the importance of diverse information sources in agricultural innovation diffusion. Demographic analysis reveals important nuances in channel effectiveness. Young farmers showed significantly higher engagement with digital platforms (Mean=3.47) compared to older farmers (Mean=1.45, p<0.001), reflecting findings by Aldosari et al. (2019) on the generational digital divide in agricultural communities. However, the universally high effectiveness of farmer-to-farmer networks across all demographic groups (means >4.38) suggests their fundamental importance in agricultural knowledge dissemination. The poor performance of digital platforms (Mean=2.23, p=0.583) and printed materials (Mean=2.78, p=0.327) aligns with research by Mittal and Mehar (2016) who found limited effectiveness of these networks in rural agricultural contexts, particularly in developing regions. This suggests careful consideration of local context and infrastructure when designing communication strategies. The findings on frequent interactions' positive effect on CSA adoption (β=0.210, p<0.001) support social learning theory and research by Foster and Rosenzweig (2010) who demonstrated how repeated interactions facilitate agricultural knowledge transfer. The overall model's substantial explanatory power (R^2=0.5784) indicates that communication network characteristics are crucial determinants of CSA adoption, supporting theoretical frameworks on innovation diffusion in agricultural systems.

These findings suggest effective CSA promotion strategies should prioritize strengthening local farmer networks while leveraging traditional networks like radio and farmer field schools. The significant demographic variations in channel preferences indicate the need for multi-channel approaches to reach different farmer segments effectively. Future research might explore how to integrate digital platforms with traditional communication networks better to enhance overall effectiveness in promoting sustainable agricultural practices.

Conclusion

The study reveals that effective communication networks are crucial in promoting Climate-Smart Agriculture (CSA) adoption for sustainable rice production in Ebonyi State. The analysis identified several highly effective communication networks, with farmer-to-farmer networks emerging as the most influential (Mean=4.51), followed by radio agricultural programs (Mean=4.37), and Farmer Field Schools (Mean=4.28). Agricultural cooperative meetings (Mean=4.05) and community meetings (Mean=3.92) also demonstrated significant effectiveness. The regression analysis confirmed that network characteristics—particularly network size (β=0.550), network diversity (β=0.307), and interaction frequency (β=0.210)—significantly influence CSA adoption rates. The study's findings emphasize that successful CSA promotion requires a multi-channel approach centred on interpersonal networks, supported by traditional media and gradually incorporating digital platforms where appropriate. Future agricultural extension efforts should strengthen these established networks while strategically integrating new communication technologies to enhance knowledge dissemination and adoption of sustainable practices among rice farmers. After the collection of data and findings, the study therefore recommends that:

1. Agricultural extension services should prioritize strengthening and leveraging farmer-to-farmer networks and local demonstration sites while providing targeted support through traditional community leaders, as these networks demonstrated the highest effectiveness (Mean=4.51) and trust levels in promoting Climate-Smart Agriculture adoption among rice farmers.

2. The government should implement a comprehensive communication strategy that combines traditional networks (radio programs, farmer field schools) with selective digital integration for younger farmers, while simultaneously addressing the significant gap in institutional communication effectiveness, particularly concerning agricultural bulletins, which showed notably poor reach (Mean=2.43) to farming communities.

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