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Extension Services, Biophysical Conditions, and Farmers' Perceptions on the Adoption of Modern Rice Production Technologies in Kambia District, Sierra Leone

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Abstract

This study examined the influence of extension services, biophysical conditions, and farmers' perceptions on the adoption of modern rice technologies in Kambia District, Sierra Leone. A cross-sectional mixed-methods research design was employed, integrating quantitative and qualitative approaches. Primary data was collected from 312 randomly selected rice farmers across Samu, Magbema, and Mambolo chiefdoms using structured questionnaires, complemented by key informant interviews and field observations. Descriptive statistics summarized respondents' characteristics, while Chi-square tests examined associations among categorical variables to identify factors influencing technology adoption. The results revealed significant variations in access to extension services among chiefdoms, including access to extension ($\chi^2 = 254.0$, df = 6, $p < 0.001$), frequency of extension visits ($\chi^2 = 234.0$, df = 6, $p < 0.001$), training participation ($\chi^2 = 226.3$, df = 8, $p < 0.001$), accessibility of extension services ($\chi^2 = 255.1$, df = 6, $p < 0.001$), and follow-up support ($\chi^2 = 236.2$, df = 6, $p < 0.001$). Membership in farmer organizations was strongly associated with participation in modern rice technology training ($\chi^2 = 131.28$, $p < 0.0001$), whereas household income source showed no significant association with training participation ($\chi^2 = 12.34$, $p = 0.195$). Significant differences were also observed in biophysical conditions, including farming systems, soil type, soil fertility, flooding frequency, and drought stress ($p < 0.05$). Results demonstrated that regular extension contact, training participation, farmer organization membership, favorable soil fertility, irrigation availability, and positive perceptions significantly increased the likelihood of adopting modern rice technologies, while poor extension access, high input costs, limited credit, and environmental constraints reduced adoption. The study concludes that strengthening extension delivery systems, expanding farmer training and demonstrations, improving access to affordable credit and production inputs, and promoting climate-smart, location-specific rice technologies are critical for enhancing technology adoption and sustainable rice productivity in Kambia District. It is recommended that improving agricultural extension services, access to agricultural credits, farmer training, cooperatives, irrigation, mechanization, and climate-smart agricultural practices will enhance rice productivity, household income, and food security in Sierra Leone.

Keywords

Agricultural Extension Services, Modern Rice Technology Adoption, Biophysical Conditions, Farmers' Perceptions, Sierra Leone

1. Introduction

Rice is one of the most important cereal crops globally and serves as a primary source of food, income, and employment for billions of people, particularly in developing regions (Abeysekara & Rathnayake, 2024; Verma et al., 2023; Mohapatra & Sahu, 2021). However, rice demand continues to increase rapidly in Africa due to population growth, urbanization, and changing dietary preferences (Bin Rahman & Zhang, 2023; De Vos et al., 2024). Despite this growing demand, many countries, especially in sub-Saharan Africa, continue to experience a substantial gap between rice production and consumption, resulting in increased dependence on imports (Glauber & Mamun, 2025; van Ittersum et al., 2025). Consequently, improving rice productivity through the promotion and adoption of modern agricultural technologies has become a major priority for achieving sustainable food security, improving rural livelihoods, and reducing vulnerability among smallholder farming households (Albahri et al., 2023; Nakashima et al., 2022).

Modern rice technologies, including improved seed varieties, mechanized land preparation, efficient water management, integrated soil fertility management, improved planting methods, and climate-smart practices, have the potential to enhance productivity, increase farm income, and improve resilience to environmental challenges (Mallareddy et al., 2023; Sandhu et al., 2021). However, their adoption is influenced by multiple interconnected factors beyond technology availability, including institutional support, biophysical conditions, socioeconomic characteristics, and farmers' perceptions (Ambali et al., 2021; Datta et al., 2026). Agricultural extension services play a vital role by providing farmers with technical knowledge, training, demonstrations, and advisory support that reduce information gaps and improve confidence in adopting new practices (Amghani et al., 2025). Nevertheless, limited extension coverage, inadequate human resources, and weak farmer-research linkages continue to hinder adoption among smallholder farmers (Mapiye & Dzama, 2024). In addition, biophysical conditions such as soil characteristics, rainfall patterns, water availability, land suitability, and climate variability determine the effectiveness and suitability of rice technologies within specific production environments (Chowdhuri et al., 2022; Hussain et al., 2020). Farmers' perceptions regarding the benefits, costs, risks, complexity, and compatibility of new technologies further shape adoption decisions, as positive perceptions encourage uptake while concerns about affordability, uncertainty, and production risks may discourage adoption (Gemtou et al., 2024; John et al., 2023). Therefore, understanding the combined influence of extension services, environmental conditions, and farmers' perceptions is essential for promoting context-specific and sustainable adoption of modern rice technologies.

In sub-Saharan Africa, improving rice production has become a strategic agricultural development priority due to increasing food demand and persistent challenges associated with low agricultural productivity (Ahmad et al., 2024; Martignoni et al., 2022). Although the region possesses considerable potential for rice cultivation, production remains constrained by limited access to improved technologies, weak extension systems, inadequate agricultural input supply chains, poor infrastructure, limited financial resources, and increasing vulnerability to climate-related challenges (Ngwoke et al., 2025; Saito et al., 2023). Several African countries have introduced rice development programmes focusing on improved seed varieties, mechanization, irrigation development, and farmer capacity building (Ngwoke et al., 2025; Mgendi et al., 2021). However, adoption levels remain inconsistent, highlighting the need to better understand the institutional, environmental, and behavioral factors influencing farmers' technology adoption decisions (Gemtou et al., 2024).

In Sierra Leone, rice is the country's most important staple food crop and plays a central role in household food security, employment generation, and rural livelihoods (Binns & Bateman, 2017). The government, development partners, and agricultural institutions have implemented various initiatives aimed at improving rice productivity through improved seed dissemination, extension support, farmer training, mechanization, and sustainable rice production practices (Patewa, 2023; Kamanda, 2022). Despite these interventions, domestic rice production remains insufficient to meet national demand, partly due to low productivity among smallholder farmers and limited adoption of modern production technologies (Kamara et al., 2023; Graham, 2020). Factors such as inadequate extension services, limited access to agricultural inputs, poor mechanization, financial constraints, and environmental challenges continue to influence farmers' capacity to adopt improved rice technologies (Becerra-Encinales et al., 2024; Bah et al., 2025). Although previous studies have examined agricultural technology adoption in Sierra Leone and other developing countries, limited empirical attention has been given to the combined influence of extension services, biophysical conditions, and farmers' perceptions on the adoption of modern rice technologies at the district level. Therefore, this study examines the influence of extension services, biophysical conditions, and farmers' perceptions on the adoption of modern rice technologies in Kambia District, Sierra Leone.

2. Research Methodology

2.1. Description of the Study Area

The study was conducted in Kambia District, located in the North-Western region of Sierra Leone. Kambia District is recognized as one of the major rice-producing areas in the country due to its favorable agro-ecological conditions, including fertile lowlands, abundant rainfall, and extensive inland valley swamp systems suitable for rice cultivation. Rice farming is the dominant agricultural activity and serves as the major source of livelihood for most rural households within the district. The study specifically focused on Robana, in Mambolo Chiefdom (8.91˚N, 13.04˚W), and Rokupr in Magbema Chiefdom (9.01˚N, −12.95˚W) and Samu Chiefdom (Kasirie and Kychom), (8.94˚N, −13.11˚W, 8.93˚N, −13.14˚W) respectively. These chiefdoms were purposively selected because of their active involvement in rice production and the observable differences in access to agricultural extension services, irrigation facilities, farmer training opportunities, and modern agricultural technologies. In addition, the selected chiefdoms exhibit varying biophysical characteristics such as soil fertility, flooding patterns, and drought conditions, making them suitable for examining the influence of extension services, biophysical conditions, and farmers' perceptions on the adoption of modern rice technologies.

2.2. Research Design

The study adopted a cross-sectional survey research design using a mixed-methods approach that combined both quantitative and qualitative research techniques. The cross-sectional design was considered appropriate because it enabled the researcher to collect information from respondents at a single point in time while examining the relationships between extension services, biophysical conditions, farmers' perceptions, and adoption of modern rice technologies. The quantitative component of the study focused on generating numerical data that could be statistically analyzed to determine patterns, associations, and determinants of adoption. Structured questionnaires were administered to rice farmers to obtain measurable information regarding socio-demographic characteristics, farm characteristics, access to extension services, and adoption behaviors.

The qualitative component involved key informant interviews and field observations aimed at obtaining in-depth explanations regarding farmers' experiences, institutional support systems, challenges associated with technology adoption, and perceptions of modern rice technologies. The combination of quantitative and qualitative approaches enhanced the reliability, validity, and comprehensiveness of the findings.

2.3. Sampling and Sampling Techniques

The study targeted all rice farmers engaged in rice production activities in Magbema, Mambolo, and Samu Chiefdoms in Kambia District, including both male and female farmers practicing rain-fed lowland, upland, and irrigated rice farming systems. Rice farmers constituted the main unit of analysis because they are directly involved in the adoption and utilization of modern rice technologies. The sampling frame consisted of 1,718 rice farmers distributed across the four selected communities: Kychum (391), Kasiri (391), Rokupr (440), and Robana (496). From these sampling frames, 312 farmers were proportionately selected, comprising 71 from Kychum, 71 from Kasiri, 80 from Rokupr, and 90 from Robana. Farmer lists were compiled with the assistance of agricultural extension officers, local authorities, farmer organizations, and community leaders and were subsequently verified to ensure that only active rice farmers were included. Individual farmers were then selected using simple random sampling to provide each eligible farmer with an equal probability of selection. Where a selected farmer was unavailable after the specified contact attempts or declined to participate, the farmer was replaced by another eligible farmer randomly selected from the same verified sampling frame. Participation was voluntary, and only farmers who provided informed consent were included in the study. The study employed a multistage sampling procedure. First, purposive sampling was used to select the three chiefdoms because of their importance in rice production and differences in extension accessibility, farming practices, and environmental conditions. Second, rice-producing communities were identified with the assistance of extension officers, local authorities, and community leaders. Finally, simple random sampling was used to select individual farmers from farmer lists to ensure equal chances of participation and reduce selection bias (Table 1). The sample size for the study was determined using the Yamane (1967) formula for sample size determination. The formula is commonly used in quantitative research to determine a representative sample from a known population.

$$n = N \Big/ \left(1 + N\left(e^2\right)\right)$$

where:

n = required sample size;

N = total population size;

e = margin of error (0.05).

Table 1. Proportionate distribution of sample size.

SN	Chiefdom	Community	Total # of Farmers	Sample Size
1	Samu	Kychum	391	71
2		Kasiri	391	71
3	Magbema	Rokupr	440	80
4	Mambolo	Robana	496	90
	GRAND TOTAL		**1,718**	**312**

2.4. Sources of Data

The study utilized both primary and secondary sources of data. Primary data were collected directly from respondents through structured questionnaires, key informant interviews, and field observations. These data focused on socio-demographic characteristics, farm characteristics, access to extension services, training opportunities, membership in farmer organizations, biophysical farming conditions, farmers' perceptions, and the adoption of modern rice technologies. The structured questionnaire served as the main instrument for collecting quantitative data from rice farmers. It consisted mainly of closed-ended questions with a few open-ended items and was administered through face-to-face interviews to accommodate respondents with low levels of formal education. In addition, key informant interviews were conducted with agricultural extension officers, farmer organization leaders, community leaders, and Ministry of Agriculture personnel to obtain qualitative information on extension delivery systems, institutional support, challenges facing rice farmers, and factors influencing technology adoption. Field observations were also conducted using an observation checklist to assess farming conditions and technology utilization practices, including irrigation facilities, soil conditions, mechanization equipment, demonstration plots, and rice farming systems. These observations helped verify information obtained from respondents. Secondary data were sourced from government reports, Ministry of Agriculture publications, agricultural policy documents, academic journals, books, previous studies, and reports from NGOs and development agencies involved in agricultural development and rice production in Sierra Leone. These sources provided background information and supported the interpretation of the study findings.

2.5. Validity and Reliability of Instruments

To ensure validity, the research instruments were reviewed by agricultural experts, research supervisors, and specialists in agricultural extension and rural development. Their comments and suggestions helped improve the clarity, relevance, and appropriateness of the questionnaire items and interview guides in relation to the study objectives. A pilot study was conducted among rice farmers outside the selected study communities to test the suitability, consistency, and clarity of the research instruments. Based on the pilot results, ambiguous questions were revised and necessary adjustments were made before the actual data collection exercise. Reliability of the instruments was ensured through careful wording of questions, proper training of research assistants, and standardization of interview procedures. Consistency in data collection procedures helped minimize errors and improve the accuracy of responses.

2.6. Data Analysis

The collected data were coded, cleaned, and analyzed using statistical software through both descriptive and inferential statistical methods. Descriptive statistics such as frequencies, percentages, means, standard deviations, and tables were used to summarize respondents' socio-demographic characteristics, extension service variables, biophysical conditions, and farmers' perceptions of modern rice technologies. Chi-square tests examined associations between categorical variables, including training participation, household income sources, and farmer organization membership. Kendall's W ranking analysis was used to assess the level of agreement among respondents on the perceived benefits, risks, constraints, and determinants of technology adoption, while post-hoc analysis identified specific group differences where significant Chi-square relationships existed.

2.7. Ethical Considerations

Ethical principles were strictly observed throughout the study. Respondents were informed about the purpose and objectives of the research before participation. Participation in the study was voluntary, and respondents were assured of confidentiality and anonymity regarding the information they provided. Informed consent was obtained from all respondents prior to data collection, and participants were allowed to withdraw from the study at any stage without penalty.

3. Results and Discussion

3.1. Demographic Characteristics of the Respondents

The socio-demographic characteristics of the 312 farmers across the three chiefdoms demonstrated notable variation in gender composition, age, and educational attainment. In Magbema, females predominated (62.5%), whereas Mambolo and Samu were largely male, representing 78.9% and 71.8% of farmers, respectively (Table 2). The farming population was predominantly mature, with mean ages of 46.3 ± 9.8 years in Magbema, 43.8 ± 8.7 years in Mambolo, and 42.1 ± 11.2 years in Samu, indicating that rice farming activities were mainly undertaken by individuals in mid-to-late adulthood. Educational attainment varied across the chiefdoms; a substantial proportion of farmers had no formal education, particularly in Mambolo (41.1%), followed by Samu (33.8%) and Magbema (32.5%). Secondary education was attained by 26.3% of farmers in Magbema, 20.0% in Mambolo, and 28.9% in Samu, while tertiary education was relatively low in all chiefdoms. Farming characteristics further highlighted differences in experience and farm size. Mean farming experience was 14.8 ± 8.9 years in Magbema, 17.6 ± 9.7 years in Mambolo, and 13.2 ± 8.5 years in Samu, indicating a generally experienced workforce. Farm sizes also differed markedly, with Magbema having the largest mean farm size (19.6 ± 14.2 acres), followed by Mambolo (12.8 ± 10.5 acres) and Samu (6.3 ± 5.7 acres).

Economic characteristics showed that rice farming was the predominant source of household income across all chiefdoms, accounting for 92.5% of farmers in Magbema, 98.9% in Mambolo, and 90.8% in Samu. Alternative income sources, including livestock, non-farm activities, and other crops, were minimally represented. Participation in farmer organizations or cooperatives varied substantially; most farmers in Magbema were cooperative members (93.8%), while only 25.4%

of Samu farmers reported membership. Mambolo had an intermediate level of cooperative participation (76.7%).

Table 2. Socio-demographic characteristics of farmers.

Variable	Category	MAGBEMA n (%)	MAMBOLO n (%)	SAMU n (%)
Gender				
	Female	50 (62.5)	19 (21.1)	40 (28.2)
	Male	30 (37.5)	71 (78.9)	102 (71.8)
	Mean ± SD (Age)	46.3 ± 9.8	43.8 ± 8.7	42.1 ± 11.2
Education Level				
	No formal education	26 (32.5)	37 (41.1)	48 (33.8)
	Primary	14 (17.5)	9 (10.0)	16 (11.3)
	Quranic	12 (15.0)	11 (12.2)	24 (16.9)
	Secondary	21 (26.3)	18 (20.0)	41 (28.9)
	Tertiary	7 (8.8)	15 (16.7)	13 (9.2)
Farming Experience (years)				
	Mean ± SD (Experience)	14.8 ± 8.9	17.6 ± 9.7	13.2 ± 8.5
	Mean ± SD (Farm Size)	19.6 ± 14.2	12.8 ± 10.5	6.3 ± 5.7
Main Source of Household Income				
	Livestock	2 (2.5)	0 (0.0)	0 (0.0)
	Non-farm activities	2 (2.5)	0 (0.0)	13 (9.2)
	Other crops	2 (2.5)	1 (1.1)	0 (0.0)
	Rice farming	74 (92.5)	89 (98.9)	129 (90.8)
Member of Farmer Organization/Cooperative				
	No	5 (6.3)	21 (23.3)	106 (74.6)
	Yes	75 (93.8)	69 (76.7)	36 (25.4)

3.2. Role of Extension Services in Farmers' Adoption Decision by Chiefdom

Adoption outcome: A farmer was classified as an adopter (1) if he or she had used at least one of the specified modern rice technologies during the study/reference period, and as a non-adopter (0) if none of the technologies had been used. The modern rice technologies considered included improved seed varieties, mechanized land preparation, improved water management/irrigation, integrated soil fertility management, improved planting methods, and climate-smart rice production practices. Extension services in Kambia District strongly influenced farmers' adoption of modern rice technologies, though access varied sharply across chiefdoms. Magbema (71.3%) and Mambolo (83.3%) farmers reported regular access, whereas 79.6% of Samu farmers had no access (χ^2 = 254, df = 6, p < .001) (**Table 3**) (Lamptey, 2021). Extension agents visited very regularly for 65% of

Magbema and 68.9% of Mambolo farmers, but 79.6% of Samu farmers never received visits ($\chi^2 = 234$, df = 6, $p < .001$) (Maake, 2023).

Table 3. Role of extension services in shaping farmers' adoption decisions.

Variable	MAGBEMA (n = 80) Freq (%)	MAMBOLO (n = 90) Freq (%)	SAMU (n = 142) Freq (%)	Total (n = 312) Freq (%)	χ^2	df	p
Role of Extension Services in Shaping Farmers' Adoption Decision							
	Chiefdoms						
Access to agricultural extension services					254	6	<.001
No access	0 (0%)	0 (0%)	113 (79.6%)	113 (36.2%)			
Yes, but very limited	5 (6.3%)	7 (7.8%)	15 (10.6%)	27 (8.7%)			
Yes, occasional	18 (22.5%)	8 (8.9%)	13 (9.2%)	39 (12.5%)			
Yes, regular	57 (71.3%)	75 (83.3%)	1 (0.7%)	133 (42.6%)			
Frequency of extension agent visits					234	6	<.001
Never	1 (1.3%)	7 (7.8%)	113 (79.6%)	121 (38.8%)			
Occasionally	25 (31.3%)	21 (23.3%)	14 (9.9%)	60 (19.2%)			
Rarely	2 (2.5%)	0 (0%)	15 (10.6%)	17 (5.4%)			
Very regularly	52 (65%)	62 (68.9%)	0 (0%)	114 (36.5%)			
Information on modern rice technologies					237.7	6	<.001
No information	3 (3.8%)	7 (7.8%)	120 (84.5%)	130 (41.7%)			
Basic info only	16 (20%)	11 (12.2%)	11 (7.7%)	38 (12.2%)			
Not useful	0 (0%)	0 (0%)	9 (6.3%)	9 (2.9%)			
Detailed/practical	61 (76.3%)	72 (80%)	2 (1.4%)	135 (43.3%)			
Training/demonstration attendance					226.3	8	<.001
Invited but did not attend	3 (3.8%)	0 (0%)	5 (3.5%)	8 (2.6%)			
Never attended	2 (2.5%)	3 (3.3%)	123 (86.6%)	128 (41%)			
Yes, once	17 (21.3%)	9 (10%)	11 (7.7%)	37 (11.9%)			
Yes, several times	55 (68.8%)	68 (75.6%)	0 (0%)	123 (39.4%)			
Clarity of information					224	6	<.001
Clear	17 (21.3%)	12 (13.3%)	7 (4.9%)	36 (11.5%)			
Not clear at all	4 (5%)	8 (8.9%)	119 (83.8%)	131 (42%)			
Somewhat unclear	1 (1.3%)	3 (3.3%)	13 (9.2%)	17 (5.4%)			
Very clear/easy	58 (72.5%)	67 (74.4%)	3 (2.1%)	128 (41%)			
Influence of extension services on adoption					223.9	8	<.001
Low influence	1 (1.3%)	3 (3.3%)	20 (14.1%)	24 (7.7%)			
Moderate influence	4 (5%)	4 (4.4%)	28 (19.7%)	36 (11.5%)			

Continued

No influence	2 (2.5%)	7 (7.8%)	88 (61.9%)	97 (31.1%)			
Strong influence	21 (26.3%)	13 (14.4%)	4 (2.8%)	38 (12.2%)			
Very strong influence	52 (65%)	63 (70%)	2 (1.4%)	117 (37.5%)			
Most effective extension method					182.1	8	<.001
Demonstration	45 (56.3%)	68 (75.6%)	0 (0%)	113 (36.2%)			
Farm visit	17 (21.3%)	12 (13.3%)	38 (26.8%)	67 (21.5%)			
Group meetings	16 (20%)	1 (1.1%)	70 (49.3%)	87 (27.9%)			
Media (Radio)	0 (0%)	3 (3.3%)	30 (21.1%)	33 (10.6%)			
Other	2 (2.5%)	6 (6.7%)	4 (2.8%)	12 (3.8%)			
Accessibility of extension services					255.1	6	<.001
No, not at all	0 (0%)	0 (0%)	109 (76.8%)	109 (35%)			
Yes, always	54 (67.5%)	65 (72.2%)	1 (0.7%)	120 (38.5%)			
Yes, rare	1 (1.3%)	3 (3.3%)	19 (13.4%)	23 (7.4%)			
Yes, sometimes	25 (31.3%)	22 (24.4%)	13 (9.2%)	60 (19.2%)			
Follow-up support after training					236.2	6	<.001
No, not at all	2 (2.5%)	10 (11.1%)	117 (82.4%)	129 (41.3%)			
Yes, always	28 (35%)	40 (44.4%)	0 (0%)	68 (21.8%)			
Yes, rare	2 (2.5%)	7 (7.8%)	20 (14.1%)	29 (9.3%)			
Yes, sometimes	48 (60%)	33 (36.7%)	5 (3.5%)	86 (27.6%)			
Overall satisfaction					234.2	6	<.001
Dissatisfied	3 (3.8%)	7 (7.8%)	29 (20.4%)	39 (12.5%)			
Satisfied	34 (42.5%)	32 (35.6%)	15 (10.6%)	81 (26%)			
Very dissatisfied	0 (0%)	0 (0%)	98 (69%)	98 (31.4%)			
Very satisfied	43 (53.8%)	51 (56.7%)	0 (0%)	94 (30.1%)			

Detailed information reached 76.3% of Magbema and 80% of Mambolo farmers, while 84.5% of Samu farmers received none (χ^2 = 237.7, df = 6, p < .001). Training attendance was high in Magbema (68.8%) and Mambolo (75.6%), versus 86.6% of Samu farmers who never attended (χ^2 = 226.3, df = 8, p < .001) (Jaiswal, 2016). Demonstrations were most effective in Magbema (56.3%) and Mambolo (75.6%), whereas Samu farmers relied on group meetings (49.3%) and radio (21.1%) (χ^2 = 182.1, df = 8, p < .001) (Mgendi et al., 2022; Hossain et al., 2021). Accessibility, follow-up support, and satisfaction followed similar patterns, consistently favoring Magbema and Mambolo (all p < .001).

3.3. Association between Training on Modern Rice Technologies and Household Income Source

The Chi-square results in Table 3 show that there is no statistically significant association between farmers' participation in training on modern rice technologies and their main source of household income (χ^2 = 12.34, p = 0.195) (Table 4). A test of association was conducted to determine whether farmers' main source of household income was associated with their participation in training on modern rice technologies. Although the Pearson chi-square statistic was $\chi^2 = 12.34$ (df = 9, $p = 0.195$), the Pearson chi-square assumptions were not satisfied because 8 of the 16 expected cell frequencies were below 5, with particularly small expected counts for the livestock and other-crops categories. Therefore, a Monte Carlo Fisher-Freeman-Halton exact test was used to obtain a more reliable significance estimate. The Monte Carlo exact test produced a p-value of 0.122 based on 200,000 simulated tables. The result was not statistically significant at the 5% level, indicating that there was no sufficient evidence of an association between farmers' main source of household income and their participation in training on modern rice technologies (Monte Carlo exact $p = 0.122$). This implies that access to training whether formal, informal, both, or none is not determined by the type of livelihood a household depends on (Khanal, 2019; Azumah, 2019). Although rice farmers dominate all training categories, particularly among those with informal training and those who have not received training, this pattern largely reflects the fact that rice farming is the primary income source for most respondents in the district, rather than indicating any targeted training differences. Similarly, smaller groups such as those engaged in non-farm activities, livestock, or other crops show limited and scattered participation in training, but not enough to create meaningful variation across income groups (Chakrabarti, 2023). Overall, the findings suggest that training opportunities are distributed broadly but not strategically targeted based on household income sources. This highlights the need for more inclusive and better-targeted training programs that ensure equitable access for all farmer categories while also improving the relevance and effectiveness of training interventions to enhance adoption of modern rice technologies (Dharamshi et al., 2023; Saito et al., 2026).

Table 4. Chi-square test on the training of modern rice technologies associated with main source of household income.

		Training on modern rice technologies							
Main source of household income	Class	Yes Informal Training	No Training Received	Yes, both Formal & Informal Training	Yes formal Training	df	X^2	p-value (2-tailed)	Number of valid cases
Livestock	Count	0	0	0	2				2
	Expected	0.27	0.84	0.27	0.62				
Non-farm activities	Count	4	6	3	2				15
	Expected	2.02	6.3	2.02	4.66				
Other crops	Count	1	0	0	2	9	12.34	0.195	3
	Expected	0.40	1.26	0.40	0.93				
Rice farming	Count	37	125	39	91				292
	Expected	39.31	122.60	39.31	90.78				

3.4. Association between Training on Modern Rice Technologies and Membership in Farmer Organizations

The Chi-square results in Table 5 reveal a highly statistically significant association between farmers' participation in training on modern rice technologies and their membership in farmer organizations ($\chi^2 = 131.28$, $p < 0.0001$) (Table 5). This indicates that membership in farmer organizations strongly influences access to training opportunities (Ma et al., 2023; Vu et al., 2020). Farmers who belong to such organizations are far more likely to receive training, particularly formal training (92 cases) and combined formal and informal training (35 cases) (Šūmane et al., 2018; Zossou et al., 2020). In contrast, non-members are largely excluded, with the majority (101 cases) reporting that they have not received any training. The large differences between observed and expected values further confirm the strength of this relationship.

Table 5. Chi-square test on the training of modern rice technologies associated with member of farmer organization.

Member of farmer organization	Class	Training on modern rice technologies: Yes Informal Training	No Training Received	Yes, both Formal & Informal Training	Yes formal Training	df	X^2	*p*-value (2-tailed)	Number of valid cases
No	Count	19	101	7	5	3	131.28	<0.0001	132
	Expected	17.77	55.42	17.77	41.04				
Yes	Count	23	30	35	92				180
	Expected	24.23	75.58	24.23	55.96				

These findings demonstrate that farmer organizations serve as critical platforms for knowledge dissemination, capacity building, and access to agricultural innovations (Makate, 2020; Mapiye et al., 2023). Membership enhances farmers' exposure to extension services, training programs, and improved technologies, thereby increasing their likelihood of adopting modern rice practices (Zossou et al., 2020). Conversely, farmers who are not part of such groups remain significantly disadvantaged in accessing training opportunities (Leta et al., 2018). This underscores the importance of promoting and strengthening farmer organizations as an effective strategy for expanding training coverage, improving information flow, and ultimately enhancing the adoption of modern rice technologies in Kambia District.

Key informants highlighted that agricultural extension services are instrumental in promoting the adoption of modern rice technologies in Kambia District. The Farmer Field School Approach (FFSA) and on-farm demonstrations were identified as the most effective extension strategies because they enhance farmers' practical knowledge, skills, and confidence in using improved technologies. However, extension service delivery is constrained by limited mechanization, inadequate farming tools, and insufficient financial resources, which restrict training and farmer support activities. The informants emphasized that strengthening extension services through increased funding, improved access to mechanization, and expanded farmer training would significantly enhance the adoption of modern rice technologies and improve rice productivity.

3.5. Biophysical Conditions for Rice Technology Adoption among Farmers by Chiefdom

The analysis of biophysical conditions for rice technology adoption in Kambia District revealed significant differences across chiefdoms. The type of rice farming system varied substantially ($\chi^2 = 50.54$, df = 6, $p < .001$) (Table 6), with Magbema and Mambolo farmers predominantly cultivating rain-fed lowland (32.5% and 53.3%, respectively) and combined irrigated and rain-fed systems (30% and 28.9%), whereas Samu farmers relied mainly on rain-fed lowland (57.7%) and rain-fed upland systems (18.3%), and no fully irrigated systems were reported in Samu (Khumairoh et al., 2024).

Table 6. Biophysical conditions for modern rice technology adoption.

Biophysical Conditions for Modern Rice Technology Adoption							
Variable	Chiefdom			Total n (%)	X^2	df	*p*
	MAGBEMA n (%)	MAMBOLO n (%)	SAMU n (%)				
Type of rice farming system					50.54	6	<.001
Both irrigated & rain-fed	24 (30.0)	26 (28.9)	34 (23.9)	84 (26.9)			
Fully irrigated	21 (26.3)	12 (13.3)	0 (0.0)	33 (10.6)			
Rain-fed lowland	26 (32.5)	48 (53.3)	82 (57.7)	156 (50.0)			
Rain-fed upland	9 (11.3)	4 (4.4)	26 (18.3)	39 (12.5)			
Dominant soil type					134.1	6	<.001
Clay soil	2 (2.5)	4 (4.4)	67 (47.2)	73 (23.4)			
Loam soil	36 (45.0)	61 (67.8)	62 (43.7)	159 (51.0)			
Mixed soil	42 (52.5)	25 (27.8)	5 (3.5)	72 (23.1)			
Not sure	0 (0.0)	0 (0.0)	8 (5.6)	8 (2.6)			
Soil fertility rating					81.48	8	<.001
High fertile	26 (32.5)	31 (34.4)	36 (25.4)	93 (29.8)			
Low fertility	1 (1.3)	0 (0.0)	11 (7.7)	12 (3.8)			
Medium fertility	18 (22.5)	27 (30.0)	83 (58.5)	128 (41.0)			
Very high fertility	35 (43.8)	32 (35.6)	6 (4.2)	73 (23.4)			
Very low fertility	0 (0.0)	0 (0.0)	6 (4.2)	6 (1.9)			
Flooding frequency					63.27	6	<.001
Frequently	6 (7.5)	13 (14.4)	14 (9.9)	33 (10.6)			

Continued

Never	8 (10.0)	6 (6.7)	43 (30.3)	57 (18.3)			
Occasionally	33 (41.3)	39 (43.3)	78 (54.9)	150 (48.1)			
Rarely	33 (41.3)	32 (35.6)	7 (4.9)	72 (23.1)			
	Drought stress frequency				17.06	6	0.009
Frequently	0 (0.0)	0 (0.0)	1 (0.7)	1 (0.3)			
Never	28 (35.0)	26 (28.9)	63 (44.4)	117 (37.5)			
Occasionally	23 (28.8)	24 (26.7)	49 (34.5)	96 (30.8)			
Rarely	29 (36.3)	40 (44.4)	29 (20.4)	98 (31.4)			

Dominant soil types also differed significantly ($\chi^2 = 134.1$, df = 6, $p < .001$); clay soils were prevalent in Samu (47.2%), loam soils in Mambolo (67.8%) and Magbema (45%), and mixed soils were most common in Magbema (52.5%) (Teramage et al., 2023). Soil fertility ratings varied across chiefdoms ($\chi^2 = 81.48$, df = 8, $p < .001$), with very high fertility recorded in Magbema (43.8%) and Mambolo (35.6%), while Samu fields were primarily medium fertility (58.5%) (Agumas et al., 2021). Flooding frequency differed significantly ($\chi^2 = 63.27$, df = 6, $p < .001$), with occasional flooding reported by 41.3% of Magbema, 43.3% of Mambolo, and 54.9% of Samu farmers, while rare flooding was reported by 41.3%, 35.6%, and 4.9%, respectively (Michael et al., 2023). Drought stress frequency was also significantly associated with chiefdom ($\chi^2 = 17.06$, df = 6, $p = 0.009$), with most Magbema (36.3%) and Mambolo (44.4%) farmers experiencing drought rarely, and 44.4% of Samu farmers reporting no drought stress (Birhanu et al., 2021).

The key informants identified soil type and drought as the major biophysical factors influencing the adoption of modern rice technologies in Kambia District. They noted that drought reduces water availability, limiting farmers' ability to adopt improved technologies. Farmers largely depend on indigenous knowledge and local farming experience to cope with these environmental challenges. The findings suggest that promoting climate-resilient, location-specific rice technologies that complement local biophysical conditions and indigenous practices would enhance technology adoption.

3.6. Farmers' Perceptions of Benefits, Risks, and Constraints of Modern Rice Technology in Kambia District

Farmers' perceptions of modern rice technology indicate a cautious attitude toward adoption, balancing recognized benefits against perceived risks and constraints. Regarding benefits, farmers expressed only slight agreement that modern rice technologies increase rice yield (Mean = 2.04, SD = 1.30), improve rice quality (Mean = 1.92, SD = 1.26), and enhance farm income (Mean = 2.02, SD = 1.32) (**Table 7**), suggesting that while some advantages are acknowledged, their impact is not strongly endorsed (Azumah, 2019; Ton et al., 2017). In contrast, farmers perceived the risks associated with adoption to be moderate to high. The risk of financial loss was considered moderate (Mean = 3.10, SD = 1.67), whereas the likelihood of crop failure (Mean = 4.16, SD = 1.18) and potential environmental harm (Mean = 4.35, SD = 1.06) were viewed as serious concerns (Boere et al., 2019). Constraints were generally rated in the moderate range, with the high cost of inputs being the most notable limitation (Mean = 2.94, SD = 1.59), followed by lack of technical knowledge (Mean = 2.46, SD = 1.44), limited access to credit (Mean = 2.43, SD = 1.49), and inadequate extension support (Mean = 2.44, SD = 1.46) (Abdulkarim et al., 2023).

Table 7. Farmers' perception associated with adopting modern rice technology.

Farmers' perception of benefits, risks, and constraints associated with adopting modern rice technology		
Perception	Mean	Std. Deviation
Benefits		
Modern rice technologies increase rice yield	2.038	1.295
Modern technologies improve rice quality	1.917	1.258
Adoption increases farm income	2.016	1.319
Risks		
Modern rice technologies involve high financial risk	3.099	1.667
Risk of crop failure	4.16	1.179
Environmental harm	4.349	1.056
Constraints		
High cost of inputs limits adoption	2.942	1.589
Lack of technical knowledge limits adoption	2.455	1.441
Poor access to credit limits adoption	2.429	1.49
Inadequate extension support limits adoption	2.436	1.46

Key informants reported that farmers generally perceive modern rice technologies positively, particularly for their ability to increase rice yields, productivity, and household income. They explained that the adoption of mechanization and improved farming practices in recent farming seasons has resulted in higher rice production and improved harvests. These experiences have strengthened farmers' confidence in the benefits of modern rice technologies and encouraged greater interest in their adoption.

4. Conclusion and Recommendation

The study found that the adoption of modern rice technologies in Kambia District was influenced by extension services, biophysical conditions, and farmers' perceptions. Adoption levels varied among chiefdoms due to differences in access to extension support, training, farmer organizations, and production resources. Farmers with better access to extension services, demonstrations, and institutional support were more likely to adopt improved technologies. Biophysical factors, including soil fertility, flooding, drought conditions, and availability of irrigation, also affected farmers' capacity to adopt modern practices. Although farmers acknowledged the benefits of improved technologies for increasing yields, income, and rice quality, adoption was constrained by high input costs, limited access to credit, technical knowledge gaps, environmental risks, and inadequate extension support. The study concludes that improving rice technology adoption requires strengthened extension services, increased farmer training, improved access to affordable inputs and credit, and targeted interventions addressing environmental and socioeconomic constraints. It is recommended that improving agricultural extension services, access to agricultural credits, farmer training, cooperatives, irrigation, mechanization, and climate-smart agricultural practices will enhance rice productivity, household income, and food security in Sierra Leone.

Author Contributions

All the authors have contributed to the development of this manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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