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Available Resources and Factors Influencing the Adoption of Modern Rice Technologies among Farmers in Kambia District, Sierra Leone

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Abstract

This study examined the factors influencing the adoption of modern rice technologies among farmers in Kambia District. A cross-sectional survey design was employed using primary data collected from 312 rice farmers selected across three chiefdoms in four communities in Kambia District. Data were analyzed using descriptive statistics, binary logistic regression, chi-square tests, Kendall's W ranking, and post-hoc analysis to identify the major drivers and constraints influencing technology adoption. The findings revealed that rice farming in the district is predominantly undertaken by experienced smallholder farmers within economically active age groups, with 93.6% relying on rice farming as their major source of household income. However, low levels of formal education remain widespread, as 35.6% of respondents had no formal education. Although improved rice varieties such as ROK 10 and NERICA are increasingly cultivated, many farmers still depend on traditional varieties due to limited access to improved inputs and financial services. The logistic regression model showed strong explanatory power (Nagelkerke $R^2 = 0.531$; $p < 0.001$) and identified farm size, land ownership, training on modern rice technologies, and chiefdom location as significant positive factors of adoption.

Farmers with larger farms, secure land ownership, and access to training were significantly more likely to adopt modern rice technologies. Conversely, inadequate access to credit and weak extension services negatively influenced adoption. Kendall's W ranking indicated moderate agreement among respondents ($W = 0.42$; $p = 0.002$), with availability of improved inputs and affordability of technologies ranked as the most important factors of adoption. Social learning through fellow farmers and market availability also played significant roles in shaping adoption decisions. Chi-square analysis revealed no significant relationship between the type of rice cultivated and household income source ($\chi^2 = 12.12$, $p = 0.436$), whereas access to improved rice seed varieties was strongly associated with household income source ($\chi^2 = 36.49$, $p < 0.0001$). Post-hoc analysis further showed significant disparities in seed access, particularly among farmers engaged in non-farm activities and rice farming, suggesting systemic inequalities in input distribution. The study concludes that adoption of modern rice technologies in Kambia District is influenced by a complex interaction of economic, institutional, social, and resource-related factors. The study recommends strengthening extension services, improving rural credit, subsidizing inputs, expanding farmer training, and enhancing irrigation and mechanization infrastructure to promote adoption and improve rice productivity and food security.

Keywords

Modern Rice Technologies, Technology Adoption, Smallholder Rice Farmers, Improved Rice Seed Varieties, Kambia District

1. Introduction

Rice is one of the most important staple foods in Sierra Leone. The United Nations Sustainable Development Goals and feeding a growing global population require a fundamental shift in agricultural production that prioritizes sustainability and productivity [1] [2]. Agricultural technology encompasses a variety of cutting-edge techniques and procedures that influence the growth of agricultural productivity [3] [4]. The most common areas of crop technology development and promotion include irrigation, water management, weed and pest control, new strains and management regimes, and soil and soil fertility management [5]. Using increasingly modern technologies boosts output, which advances society and the economy. Increased pay for workers without land ownership, better nutritional status, cheaper staple food costs, and more job opportunities have all been associated with the adoption of more sophisticated agricultural technologies. It has also been connected to increased income and a decrease in farm households' rural squalor [6]-[8]. Thus, economic prosperity and long-term food security depend on a new agricultural innovation that enhances sustainable food production. However, policymaking requires a thorough understanding of farmers' behavioral

intentions to embrace rice technology, particularly in developing nations where socio-economic and engineering factors pose significant obstacles to technology adoption [9]. Research has given governments, farming associations, and technology suppliers ways to enhance the use of technology in the agricultural industry [10] [11]. Hence, low agricultural output and food insecurity in the Sub-Saharan African region are commonly attributed to traditional institutions and technology [12]. Non-adopters of agricultural technology struggle to make ends meet and are more likely to encounter socio-economic stagnation, which frequently results in poverty [13]. Due to their various obstacles, smallholder farmers in developing countries are particularly in need of these technologies and should be the primary focus of development programs [14] [15]. Barriers to increased agricultural productivity, conventional practices, tenure systems, and other institutions are also seen as pseudoscientific, outdated, useless, vulgar, incorrect, and erroneous [16] [17]. It is feasible to increase agricultural productivity, technology adoption rates, household food security, and nutrition by improving agricultural practices, growing the rural financial sector, motivating the rural populace to acquire more capital and equipment, and establishing connections between research and extension [18] [19].

The adoption of modern rice technologies in Sierra Leone is currently in a transitional state, moving from traditional, subsistence-based farming toward improved, technology-driven methods, though at a slow and inconsistent pace. While the government and development partners are actively promoting improved varieties (such as NERICA and ROK series), fertilizers, and specialized, participatory farming approaches (like Smart Valley) to boost production, adoption rates among smallholder farmers remain highly challenged. Agriculture needs to become more productive in order to meet the growing demand for food. Increasing food productivity is significantly impacted by agricultural technologies [20] [21]. Consequently, this study examines the factors that affect farmer's adoption of modern rice technologies and management practices in selected communities in Sierra Leone.

2. Research Methodology

2.1. Research Design

This study employed a descriptive cross-sectional survey design supported by quantitative analytical approaches to examine the factors influencing the adoption of modern rice technologies among farmers in Kambia District, Sierra Leone. The design was appropriate because it enabled the researchers to collect data from a large number of respondents at a single point in time while analyzing relationships between socio-economic, institutional, and technological factors affecting adoption behavior. Inferential statistical techniques such as logistic regression analysis, chi-square tests, post-hoc analysis, and Kendall's coefficient of concordance (Kendall's W) were incorporated to identify significant predictors and associations

among variables.

2.2. Description of Study Area

The study was conducted in Kambia District in the Northern Province of Sierra Leone, one of the major rice-producing regions in the country. The district is characterized by inland valley swamps, bolilands, and upland farming systems suitable for rice cultivation. The study was conducted across three chiefdoms in four communities in Kambia District, namely Kasiri, Kychon, in Samu Chiefdom (8.94˚N, −13.11˚W, 8.93˚N, −13.14˚W), respectively, Robana, in Mambolo Chiefdom (8.91˚N, 13.04˚W), and Rokupr in Magbema Chiefdom (9.01˚N, −12.95˚W) were purposively selected due to their high involvement in rice farming and varying levels of access to agricultural technologies and support services. The target population consisted of registered and non-registered rice farmers actively engaged in rice production during the 2025/2026 farming season, including both male and female farmers, smallholder and medium-scale producers, as well as members and non-members of farmer organizations.

2.3. Sampling and Sampling Techniques

A total sample size of 312 rice farmers was used for the study. The respondents were proportionately distributed across the selected chiefdoms as follows: Kasiri (71), Kychon (71), Robana (90), and Rokupr (80). The study adopted a multi-stage sampling procedure involving purposive, stratified, and simple random sampling techniques. First, the chiefdoms were purposively selected based on rice production activities and accessibility. Second, farmers were stratified according to chiefdom, gender, membership in farmer organizations, and type of rice cultivated to ensure balanced representation. Finally, simple random sampling was used to select respondents from farmer lists obtained from cooperatives and extension officers. The sample size for the study was determined using the Yamane [22] formula for sample size determination. The formula is commonly used in quantitative research to determine a representative sample from a known population (**Table 1**).

$$n = N/(1 + N(e^2))$$

where:

n = required sample size;

N = total population size;

e = margin of error (0.05).

2.4. Sources of Data Collection

Both primary and secondary data sources were utilized in the study. Primary data were collected through structured questionnaires, field interviews, and farmer consultations, while secondary data were obtained from Ministry of Agriculture reports, Food and Agriculture Organization publications, agricultural policy documents, journals, extension service records, and rice development project reports.

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			**1718**	**312**

The questionnaire contained both closed-ended and multiple-choice questions designed to capture information on demographic characteristics, farming experience, farm size, and access to agricultural inputs, irrigation, credit, extension services, training opportunities, and adoption of modern rice technologies. The instrument was reviewed by agricultural experts and supervisors to ensure content and face validity, while pre-testing was conducted in a nearby farming community outside the study area to improve clarity and reliability. A pilot survey was also carried out to test internal consistency, and ambiguous items were revised accordingly.

Data collection was conducted through face-to-face interviews administered by trained research assistants familiar with local languages and farming practices. Permission was obtained from local authorities and farmer leaders before data collection commenced. Respondents were informed about the purpose of the study, and their participation was voluntary. Interviews were preferred because many respondents had low levels of formal education, making self-administered questionnaires unsuitable. The dependent variable in the study was the adoption of modern rice technologies, coded as 1 for adopters and 0 for non-adopters. Independent variables included age, gender, education level, farming experience, farm size, land ownership, access to fertilizer, access to machinery, irrigation availability, access to credit, extension services, training opportunities, labour availability, farmer organization membership, chiefdom location, input availability, and main source of household income.

Qualitative data were collected through Key Informant Interviews (KIIs) with purposively selected stakeholders who had extensive knowledge of rice production and technology dissemination in the study area. The key informants included agricultural extension officers, rice farmer association leaders, community leaders, agricultural input dealers, representatives of non-governmental organizations, and officials from relevant agricultural institutions. A semi-structured interview guide was used to explore the availability of resources and factors influencing the adoption of modern rice technologies, including access to improved seeds, credit facilities, extension services, farm inputs, training opportunities, market access, and institutional support. Interviews were conducted face-to-face, recorded with participants' consent, and supplemented with field notes. The qualitative data provided detailed insights into the opportunities and constraints affecting farmers' decisions

to adopt modern rice technologies and were used to complement and validate the quantitative survey findings.

2.5. Data Analysis

Binary logistic regression analysis was employed to determine the factors influencing adoption of modern rice technologies. The model estimated the probability of adoption using socio-economic and institutional predictors, while model fitness was assessed using deviance statistics, Akaike Information Criterion (AIC), Bayesian Information Criterion (BIC), McFadden R^2, Nagelkerke R^2, Cox and Snell R^2, and Tjur R^2. Chi-square tests were used to examine relationships between categorical variables such as rice variety cultivated and household income source, as well as access to improved seed varieties and income source. Where significant associations were identified, post-hoc pairwise comparisons with Bonferroni correction were conducted to determine specific group differences. Kendall's coefficient of concordance (Kendall's W) was also used to measure the level of agreement among farmers regarding the ranking of factors influencing adoption of modern rice technologies.

Key Informant Interview (KII) data were analyzed using thematic content analysis. Interview recordings were transcribed verbatim and carefully reviewed to identify recurring patterns and emerging issues. Responses were coded and grouped into themes based on similarities in meaning and relevance to the study objectives. Major themes identified included observed weather changes, climate-related agricultural challenges, impacts on farming systems, and adaptation constraints. The qualitative findings were subsequently triangulated with quantitative survey results to enhance the validity and depth of interpretation. Representative quotations from key informants were used to illustrate key themes and provide contextual explanations for the quantitative findings. This approach enabled a comprehensive understanding of farmers' experiences and perceptions regarding climate change and its effects on agricultural livelihoods.

2.6. Ethical Consideration

Ethical considerations were strictly observed throughout the study. Respondents participated voluntarily, informed consent was obtained, and confidentiality and anonymity of responses were guaranteed. Participants were assured that the information provided would be used strictly for academic purposes. Despite challenges such as limited financial resources, poor road accessibility, low literacy levels among respondents, incomplete farmer records, and time constraints, adequate measures were taken to ensure the reliability and validity of the study findings.

3. Results and Discussion

3.1. Demographic Characteristics of the Respondents

The results from **Table 2** reveal that rice farmers in Kambia District are predom-

inantly male (65.1%), although female participation is notably high in Rokupr (62.5%), indicating some gender variation across chiefdoms. The age distribution shows that most farmers fall within the economically active age groups (33 - 57 years), suggesting a relatively mature and experienced farming population, which is further supported by the finding that a large proportion have 11 - 20 years of farming experience, suggesting that rice farming is largely undertaken by mature farmers with substantial practical knowledge [23]-[25]. Educationally, the majority of respondents have low levels of formal education, with 35.6% having no formal schooling and only a small proportion attaining tertiary education, which may limit access to agricultural information, extension services, and the effective adoption of modern rice technologies [26]-[28]. Farm sizes are generally small to medium-scale (2 - 5 acres), reflecting the dominance of smallholder farming, although a few farmers manage larger holdings. Rice farming is the primary source of household income (93.6%), highlighting its central role in livelihoods and food security in the district [29] [30]. In addition, more than half (57.7%) of respondents belong to farmer organizations, particularly in Robana and Rokupr, which may improve access to information, inputs, and collective support systems [31] [32]. The findings indicate that rice production in Kambia is largely driven by experienced smallholder farmers with limited education but strong dependence on agriculture, with variations in gender roles, organizational membership, and resource access across chiefdoms.

Table 2. Demographic characteristics of respondents.

Demographic Characteristics	Kambia (N = 312)									
	Kasiri		Kychon		Robana		Rokupr		Total	
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Gender										
Male	48	67.6	54	76.1	71	78.9	30	37.5	203	65.1
Female	23	32.4	17	23.9	19	21.1	50	62.5	109	34.9
Age group (years)										
18 - 22	5	7.0	0	0.0	0	0.0	0	0.0	5	1.6
23 - 27	6	8.5	5	7.0	3	3.3	2	2.5	16	5.1
28 - 32	10	14.1	3	4.2	4	4.4	5	6.3	22	7.1
33 - 37	9	12.7	12	16.9	11	12.2	11	13.8	43	13.8
38 - 42	5	7.0	5	7.0	19	21.1	6	7.5	35	11.2
43 - 47	10	14.1	10	14.1	18	20.0	16	20.0	54	17.3
48 - 52	9	12.7	20	28.2	23	25.6	20	25.0	72	23.1
53 - 57	8	11.3	12	16.9	9	10.0	10	12.5	39	12.5
58 - 62	5	7.0	4	5.6	1	1.1	7	8.8	17	5.4
63 - 67	4	5.6	0	0.0	2	2.2	3	3.8	9	2.9

Continued

Education level										
Quranic	6	8.5	18	25.4	11	12.2	12	15.0	47	15.1
No formal education	18	25.4	30	42.3	37	41.1	26	32.5	111	35.6
Primary	10	14.1	6	8.5	9	10.0	14	17.5	39	12.5
Secondary	27	38.0	14	19.7	18	20.0	21	26.3	80	25.6
Tertiary	10	14.1	3	4.2	15	16.7	7	8.8	35	11.2
Farming experience (years)										
1 - 5	3	4.2	6	8.5	5	5.6	7	8.8	21	6.7
6 - 10	20	28.2	19	26.8	14	15.6	18	22.5	71	22.8
11 - 15	14	19.7	22	31.0	20	22.2	26	32.5	82	26.3
16 - 20	14	19.7	11	15.5	17	18.9	13	16.3	55	17.6
21 - 30	12	16.9	5	7.0	22	24.4	12	15.0	51	16.3
31 - 35	4	5.6	4	5.6	9	10.0	2	2.5	19	6.1
36 - 40	2	2.8	1	1.4	2	2.2	0	0.0	5	1.6
41 - 45	2	2.8	3	4.2	1	1.1	2	2.5	8	2.6
Size of rice farm (acres)										
1	4	5.6	4	5.6	0	0.0	1	1.3	9	2.9
2	20	28.2	14	19.7	5	5.6	0	0.0	39	12.5
3	14	19.7	11	15.5	2	2.2	2	2.5	29	9.3
4	11	15.5	19	26.8	7	7.8	5	6.3	42	13.5
5	8	11.3	10	14.1	17	18.9	10	12.5	45	14.4
6	2	2.8	0	0.0	4	4.4	5	6.3	11	3.5
7	3	4.2	0	0.0	6	6.7	5	6.3	14	4.5
8	4	5.6	5	7.0	10	11.1	1	1.3	20	6.4
9	1	1.4	0	0.0	0	0.0	1	1.3	2	0.6
10	3	4.2	3	4.2	6	6.7	11	13.8	23	7.4
12	0	0.0	0	0.0	2	2.2	2	2.5	4	1.3
14	0	0.0	3	4.2	0	0.0	0	0.0	3	1.0
15	0	0.0	0	0.0	7	7.8	1	1.3	8	2.6
18	0	0.0	0	0.0	0	0.0	2	2.5	2	0.6
20	0	0.0	0	0.0	8	8.9	7	8.8	15	4.8
25	1	1.4	0	0.0	1	1.1	4	5.0	6	1.9
30	0	0.0	2	2.8	3	3.5	3	3.8	8	2.6
35	0	0.0	0	0.0	4	4.4	9	11.3	13	4.2
40	0	0.0	0	0.0	2	2.2	2	2.5	4	1.3
45	0	0.0	0	0.0	1	1.1	1	1.3	2	0.6
50	0	0.0	0	0.0	2	2.2	3	3.8	5	1.6

Continued

55	0	0.0	0	0.0	1	1.1	0	0.0	1	0.3
59	0	0.0	0	0.0	0	0.0	1	1.3	1	0.3
60	0	0.0	0	0.0	1	1.1	0	0.0	1	0.3
70	0	0.0	0	0.0	0	0.0	2	2.5	2	0.6
90	0	0.0	0	0.0	0	0.0	2	2.5	2	0.6
100	0	0.0	0	0.0	1	1.1	0	0.0	1	0.3
Main source of household income										
Rice farming	63	88.7	66	93.0	89	98.9	74	92.5	292	93.6
Other crops	0	0.0	0	0.0	1	1.1	2	2.5	3	1.0
Livestock	0	0.0	0	0.0	0	0.0	2	2.5	2	0.6
Non-farm activities	8	11.3	5	7.0	0	0.0	2	2.5	15	4.8
Member of farmer organization										
Yes	24	33.8	12	16.9	69	76.7	75	93.8	180	57.7
No	47	66.2	59	83.1	21	23.3	5	6.3	132	42.3

3.2. Access to Available Resources for Adoption of Modern Rice Technologies

The findings indicate that access to key resources for adopting modern rice technologies in Kambia District is uneven and highly dependent on location, with better access generally observed in Robana and Rokupr compared to Kasiri and Kychon (**Table 3**). A majority of farmers cultivate improved varieties such as ROK 10 (55.1%), though a significant proportion still rely on traditional varieties (27.9%), especially in less advantaged chiefdoms. Access to improved seeds and fertilizers is relatively strong in Robana and Rokupr but remains limited in Kasiri and Kychon, where many farmers report no access [33] [34]. Mechanization is generally low, with only 1.6% owning machinery, while most farmers either rent/borrow (43.3%) or have no access at all (45.2%) [35] [36]. Similarly, irrigation is inadequate, as 41.4% depend solely on rainfall, highlighting vulnerability to climate variability and drought risks [37] [38]. Financially, farmers rely mainly on personal savings (38.8%) and cooperatives (34.0%), with minimal access to formal banking services, and half of respondents reported that credit is never available when needed [39]. Training on modern technologies is also limited, with 42% receiving no training, particularly in Kasiri and Kychon [40]. Labour availability varies, being more sufficient in Robana and Rokupr, while land access is dominated by rented (43.9%) and leased systems**,** indicating tenure insecurity. Additionally, timely availability of inputs remains a challenge, with delays or shortages reported by many farmers. The results suggest that while some progress has been made in improving access to inputs and support services, significant constraints in finance, training, irrigation, mechanization, and input distribution continue to limit the widespread adoption of modern rice technologies across the district [41] [42].

The qualitative findings revealed that "rice farmers in the study areas have access to limited forms of resources that support the adoption of modern rice technologies. Respondents identified both physical and human resources as the main resources currently available. Physical resources included basic farming tools, land, and labor, while human resources mainly referred to agricultural extension workers and experienced farmers who provide technical guidance and farming advice. However, participants explained that these resources are inadequate to fully support large-scale adoption of modern rice technologies".

A significant chiefdom effect was observed in the adoption of modern rice technologies, indicating that adoption rates varied across locations due to differences in local resource availability and institutional support. Chiefdoms with higher adoption levels generally had better access to improved seed varieties, farmer training programs, extension services, and agricultural inputs, which enhanced farmers' knowledge and confidence in using modern technologies. Differences in irrigation facilities and reliable water sources also influenced adoption, as farmers with access to irrigation were more willing to invest in improved practices than those relying solely on rainfall. Similarly, greater availability of mechanization services, such as tractors and threshers, reduced labour constraints and facilitated technology uptake. Qualitative findings further revealed that some chiefdoms benefited from stronger support from government agencies, NGOs, and agricultural development projects, leading to increased training, input distribution, and technical assistance. Hence, the chiefdom effect reflects spatial inequalities in access to resources, extension services, irrigation infrastructure, mechanization, and institutional support, highlighting the need for targeted interventions to ensure equitable dissemination of modern rice technologies across all chiefdoms in Kambia District.

Table 3. Access to available resources for adoption of modern rice technologies.

Access to Available Resources	Kambia (N = 312)									
	Kasiri		Kychon		Robana		Rokupr		Total	
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Type of rice cultivated										
ROK 10	18	25.4	33	46.5	62	68.9	59	73.8	172	55.1
NERICA	4	5.6	6	8.5	12	13.3	13	16.3	35	11.2
Traditional varieties	42	59.2	29	40.8	13	14.4	3	3.8	87	27.9
Deepwater rice	3	4.2	3	4.2	3	3.3	4	5.0	13	4.2
None	4	5.6	0	0.0	0	0.0	1	1.3	5	1.6
Access to improved rice seed varieties										
Yes, regularly	6	8.5	3	4.2	81	90.0	67	83.8	157	50.3
Yes, occasionally	3	4.2	13	18.3	9	10.0	11	13.8	36	11.5

Continued

Rarely	7	9.9	2	2.8	0	0.0	0	0.0	9	2.9
No access	55	77.5	53	74.6	0	0.0	2	2.5	110	35.3
Access to chemical fertilizers for rice production										
Always available when needed	13	18.3	14	19.7	60	66.7	58	72.5	145	46.5
Sometimes available	9	12.7	16	22.5	26	28.9	20	25.0	71	22.8
Rarely available	1	1.4	4	5.6	0	0.0	0	0.0	5	1.6
Not available	48	67.6	37	52.1	4	4.4	2	2.5	91	29.2
Level of access to farm machinery (tractor, power tiller, thresher)										
Own machinery	2	2.8	0	0.0	3	3.3	0	0.0	5	1.6
Rent/borrow machinery	9	12.7	10	14.1	61	67.8	55	68.8	135	43.3
Access through cooperative	0	0.0	0	0.0	12	13.3	18	22.5	30	9.6
No access to machinery	59	83.1	61	85.9	14	15.6	7	8.8	141	45.2
None	1	1.4	0	0.0	0	0.0	0	0.0	1	0.3
Level of irrigation water availability for your rice farm										
Available throughout the growing season	0	0.0	0	0.0	56	62.2	48	60.0	104	33.3
Available only part of the season	9	12.7	11	15.5	31	34.4	19	23.8	70	22.4
Rarely available	4	5.6	5	7.0	0	0.0	0	0.0	9	2.9
Not available (rain-fed only)	58	81.7	55	77.5	3	3.3	13	16.3	129	41.4
Main source of finance for rice farming										
Personal savings	45	63.4	40	56.3	23	25.6	13	16.3	121	38.8
Bank loan	0	0.0	0	0.0	0	0.0	4	5.0	4	1.3
Microfinance institution	1	1.4	1	1.4	24	26.7	17	21.3	43	13.8
Farmer cooperative	11	15.5	14	19.7	39	43.3	42	52.5	106	34.0
Friends or relatives	13	18.3	16	22.5	4	4.4	4	5.0	37	11.9
Government support/subsidy	1	1.4	0	0.0	0	0.0	0	0.0	1	0.3
Training on modern rice technologies										
Yes, formal training (extension, NGO, research institution)	4	5.6	2	2.8	49	54.4	42	52.5	97	31.1
Yes, informal training (other farmers, self-learning)	2	2.8	10	14.1	14	15.6	16	20.0	42	13.5
Yes, both formal and informal	2	2.8	4	5.6	20	22.2	16	20.0	42	13.5
No training received	63	88.7	55	77.5	7	7.8	6	7.5	131	42.0
Access to agricultural credit when needed										
Always available	1	1.4	0	0.0	44	48.9	27	33.8	72	23.1

Continued

Often available	5	7.0	6	8.5	4	4.4	15	18.8	30	9.6
Sometimes available	1	1.4	4	5.6	21	23.3	28	35.0	54	17.3
Never available	64	90.1	61	85.9	21	23.3	10	12.5	156	50.0
Land ownership for rice farming										
Fully owned	11	15.5	22	31.0	30	33.3	9	11.3	72	23.1
Rented	23	32.4	40	56.3	31	34.4	43	53.8	137	43.9
Leased	36	50.7	8	11.3	4	4.4	8	10.0	56	18.0
Communal/family land	0	0.0	1	1.4	25	27.8	20	25.0	46	14.7
Sharecropping	1	1.4	0	0.0	0	0.0	0	0.0	1	0.3
Farm inputs availability on time in locality										
Always available on time	15	21.1	4	5.6	42	46.7	39	48.8	100	32.1
Often available with minor delays	19	26.8	24	33.8	42	46.7	36	45.0	121	38.8
Rarely available on time	10	14.1	4	5.6	0	0.0	3	3.8	17	5.5
Not available on time	27	38.0	39	54.9	6	6.7	2	2.5	74	23.7

3.3. Logistic Regression Model Summary for the Adoption of Modern Rice Technology

The logistic regression analysis assessed the factors of modern rice technology adoption among farmers, incorporating a range of socio-demographic, economic, and resource-related variables. The logistic regression model significantly improved the explanation of adoption behavior compared to the null model, as indicated by the reduction in deviance from 397.2 to 246.7 and the highly significant chi-square value ($\Delta\chi^2 = 150.49$, $p < 0.001$) (**Table 4**). This confirms that the selected socio-economic and institutional variables collectively explain variations in farmers' adoption of modern rice technologies [43] [44]. The explanatory power of the model was relatively strong, with McFadden $R^2 = 0.379$, Cox and Snell $R^2 = 0.383$, Nagelkerke $R^2 = 0.531$, and Tjur $R^2 = 0.427$. These statistics suggest that the included predictors account for approximately 38% - 53% of the variation in adoption behavior [45] [46]. Overall, the model demonstrates that factors such as access to resources, institutional support, and farm characteristics are important in influencing farmers' technology adoption decisions [47] [48].

The logistic regression analysis examined the factors associated with modern rice technology adoption among farmers using socio-demographic, economic, and resource-related variables. The model significantly improved the explanation of adoption behavior compared to the null model, as evidenced by the reduction in deviance from 397.2 to 246.7 and the highly significant likelihood ratio chi-square statistic ($\Delta\chi^2 = 150.49$, $p < 0.001$) (**Table 4**), indicating that the included variables collectively contribute to explaining adoption decisions (Assaye *et al.*, 2023; Melaku Baye *et al.*, 2025) [43] [44]. The model also demonstrated good fit, with McFadden $R^2 = 0.379$, Cox and Snell $R^2 = 0.383$, Nagelkerke $R^2 = 0.531$, and

Tjur R^2 = 0.427. However, these pseudo-R^2 measures should be interpreted cautiously, as they are not directly comparable to the R^2 statistic used in ordinary least squares regression. Consistent with Train (1977) [49], who suggested that values between 0.20 and 0.40 indicate excellent model fit in logistic regression, the results suggest that the model provides substantial explanatory capacity and effectively distinguishes adopters from non-adopters rather than explaining a fixed percentage of variation in adoption behavior.

Table 4. Logistic regression model summary for the adoption of modern rice technology.

Model	Deviance	AIC	BIC	df	$\Delta\chi^2$	p	McFadden R^2	Nagelkerke R^2	Tjur R^2	Cox & Snell R^2
M_0	397.2	399.185	402.928	311			0.000		0.000	
M_1	246.7	274.693	327.095	298	150.492	<0.001	0.379	0.531	0.427	0.383

Note: M_1 includes What is the level of access to farm machinery (tractor, power tiller, thresher)?, Do you own the land used for 0?, Age, Education level, Farm size, Main source of household income, Access to fertilizer, Access to credit, Access to extension services, Training on modern rice technologies, Is labour readily available during peak farming periods?, Are farm inputs available on time in your locality?, Name of Chiefdom (IN CAP).

3.4. Major Factors Influencing Adoption of Modern Rice Technologies

The findings indicate that the adoption of modern rice technologies in Kambia District is primarily driven by economic and productivity-related factors, alongside institutional and socio-cultural influences, with noticeable variation across chiefdoms (Table 5). Key factors such as the cost of technologies (46.5%), expected increase in yield (48.7%), and availability of improved inputs (43.3%) emerged as the most influential, showing that farmers are largely motivated by profitability but constrained by affordability and access [50]. Factors like access to credit (34.3%) and availability of labour (34.9%) also play important but less consistent roles, reflecting financial and labour challenges [51]. Institutional and social influences, including extension services (37.5%) and peer learning from fellow farmers (32.4%), significantly enhance adoption, especially in Robana and Rokupr, emphasizing the importance of information sharing and advisory support [52] [53]. In contrast, chiefdoms such as Kasiri and Kychon recorded lower influence across several factors, suggesting disparities in access to resources and services. Meanwhile, education level and farming experience showed moderate influence, acting as supportive rather than primary drivers. Market availability presented mixed effects across locations. Overall, adoption is shaped by a combination of affordability, expected benefits, input access, and institutional support, and can be improved through targeted policies such as subsidies, better input distribution, strengthened extension services, rural financing, and farmer training to address local inequalities [54] [55]. The qualitative findings revealed that "limited access to modern agricultural tools and inadequate technical knowledge are major factors influencing farmers' decisions regarding the adoption of modern rice tech-

nologies. Respondents explained that many farmers are unable to adopt improved technologies because they lack the necessary support, equipment, and practical training required for effective utilization. Farmers further stated that inadequate knowledge on the operation and management of modern technologies, particularly in large-scale rice farming, discourages adoption and reduces confidence in using improved farming methods".

Table 5. Major factors influencing adoption of modern rice technologies.

Major Factors	Kambia (N = 312)									
	Kasiri		Kychon		Robana		Rokupr		Total	
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Cost of modern rice technologies										
Very strong influence	15	21.1	11	15.5	60	66.7	59	73.8	145	46.5
Strong influence	0	0.0	6	8.5	25	27.8	19	23.8	50	16.0
Moderate influence	28	39.4	4	5.6	5	5.6	1	1.3	38	12.2
Low influence	13	18.3	31	43.7	0	0.0	0	0.0	44	14.1
No influence	15	21.1	19	26.8	0	0.0	1	1.3	35	11.2
Expected increase in rice yield										
Very strong influence	13	18.3	6	8.5	72	80.0	61	76.3	152	48.7
Strong influence	8	11.3	8	11.3	16	17.8	17	21.3	49	15.7
Moderate influence	33	46.5	13	18.3	2	2.2	1	1.3	49	15.7
Low influence	17	23.9	44	62.0	0	0.0	1	1.3	62	19.9
No influence	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Availability of improved inputs										
Very strong influence	11	15.5	1	1.4	71	78.9	52	65.0	135	43.3
Strong influence	7	9.9	5	7.0	16	17.8	22	27.5	50	16.0
Moderate influence	13	18.3	17	23.9	3	3.3	4	5.0	37	11.9
Low influence	22	31.0	11	15.5	0	0.0	1	1.3	34	10.9
No influence	18	25.4	37	52.1	0	0.0	1	1.3	56	18.0
Access to credit facilities										
Very strong influence	2	2.8	1	1.4	55	61.1	49	61.3	107	34.3
Strong influence	14	19.7	3	4.2	21	23.3	22	27.5	60	19.2
Moderate influence	10	14.1	16	22.5	2	2.2	3	3.8	31	9.9
Low influence	24	33.8	14	19.7	11	12.2	5	6.3	54	17.3
No influence	21	29.6	37	52.1	1	1.1	1	1.3	60	19.2
Level of education										
Very strong influence	1	1.4	0	0.0	35	38.9	17	21.3	53	17.0
Strong influence	9	12.7	2	2.8	37	41.1	37	46.3	85	27.2

Continued

Moderate influence	19	26.8	19	26.8	4	4.4	18	22.5	60	19.2
Low influence	22	31.0	16	22.5	12	13.3	5	6.3	55	17.6
No influence	20	28.2	34	47.9	2	2.2	3	3.8	59	18.9
Farming experience										
Very strong influence	3	4.2	0	0.0	62	68.9	39	48.8	104	33.3
Strong influence	8	11.3	2	2.8	28	31.1	37	46.3	75	24.0
Moderate influence	25	35.2	15	21.1	0	0.0	3	3.8	43	13.8
Low influence	13	18.3	20	28.2	0	0.0	0	0.0	33	10.6
No influence	22	31.0	34	47.9	0	0.0	1	1.3	57	18.3
Availability of labour										
Very strong influence	2	2.8	0	0.0	59	65.6	48	60.0	109	34.9
Strong influence	5	7.0	5	7.0	18	20.0	25	31.3	53	17.0
Moderate influence	21	29.6	11	15.5	8	8.9	2	2.5	42	13.5
Low influence	21	29.6	19	26.8	5	5.6	5	6.3	50	16.0
No influence	22	31.0	36	50.7	0	0.0	0	0.0	58	18.6
Extension agents influence on decision										
Very strong influence	0	0.0	0	0.0	66	73.3	51	63.7	117	37.5
Strong influence	8	11.3	3	4.2	17	18.9	24	30.0	52	16.7
Moderate influence	18	25.4	15	21.1	2	2.2	2	2.5	37	11.9
Low influence	20	28.2	16	22.5	3	3.3	2	2.5	41	13.1
No influence	25	35.2	37	52.1	2	2.2	1	1.3	65	20.8
Fellow farmers										
Very strong influence	1	1.4	0	0.0	59	65.6	41	51.2	101	32.4
Strong influence	9	12.7	2	2.8	31	34.4	36	45.0	78	25.0
Moderate influence	22	31.0	18	25.4	0	0.0	1	1.3	41	13.1
Low influence	19	26.8	15	21.1	0	0.0	1	1.3	35	11.2
No influence	20	28.2	36	50.7	0	0.0	1	1.3	57	18.3
Market availability for rice										
Very strong influence	2	2.8	0	0.0	57	63.3	38	47.5	97	31.1
Strong influence	8	11.3	3	4.2	33	36.7	28	35.0	72	23.1
Moderate influence	13	18.3	16	22.5	0	0.0	12	15.0	41	13.1
Low influence	48	67.6	52	73.2	0	0.0	2	2.5	102	32.7
No influence	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0

3.5. Logistic Regression Analysis of Factors of Modern Rice Technology Adoption

The logistic regression analysis identified key factors of modern rice technology adoption among farmers. Ownership of land significantly increased the likelihood

of adoption, with farmers who owned their land being approximately 2.85 times more likely to adopt modern technologies compared to those who did not (OR = 2.854, p = 0.005) (Table 6). Farm size also emerged as a strong positive predictor, with larger farms associated with a markedly higher likelihood of adoption (OR = 7.329, p < 0.001) [54] [56] [57]. Training on modern rice technologies substantially enhanced adoption, with trained farmers nearly seven times more likely to implement these technologies than untrained farmers (OR = 6.659, p < 0.001) [56] [58]. Geographic location, represented by the chiefdom of residence, was another significant factor, with farmers in certain towns exhibiting a 2.76-fold higher probability of adoption (OR = 2.757, p = 0.023). In contrast, limited access to credit (OR = 0.110, p = 0.047) and extension services (OR = 0.308, p = 0.021) were negatively associated with adoption, indicating that inadequate financial and technical support can constrain uptake [58] [59]. Other variables, including age, education level, household income source, labor availability, and timely access to inputs, were not statistically significant predictors.

Table 6. Logistic regression analysis of factors of modern rice technology adoption.

Coefficients								
						Wald Test		
Model		Estimate	Standard Error	Odds Ratio	z	Wald Statistic	df	p
M_0	(Intercept)	−0.693	0.120	0.500	−5.772	33.311	1	<0.001
M_1	(Intercept)	−2.592	0.419	0.075	−6.182	38.219	1	<0.001
	Farm machinery access	0.672	0.364	1.958	1.848	3.414	1	0.065
	Land tenure status	1.049	0.376	2.854	2.789	7.776	1	0.005
	Age category	−0.125	0.456	0.882	−0.275	0.076	1	0.783
	Education level	0.190	0.453	1.209	0.418	0.175	1	0.676
	Farm size	1.992	0.556	7.329	3.585	12.849	1	<0.001
	Household income source	0.621	1.345	1.860	0.461	0.213	1	0.644
	Fertilizer access	−0.819	0.453	0.441	−1.807	3.264	1	0.071
	Credit access	−2.207	1.109	0.110	−1.990	3.960	1	0.047
	Extension service access	−1.177	0.509	0.308	−2.314	5.353	1	0.021
	Technology	1.896	0.463	6.659	4.099	16.804	1	<0.001
	Labour availability	−0.417	0.429	0.659	−0.973	0.946	1	0.331
	Timely Input availability	−16.054	869.339	1.066×10^{-7}	−0.018	3.410×10^{-4}	1	0.985
	Chiefdom Location	1.014	0.445	2.757	2.280	5.196	1	0.023

Note: Adoption of modern rice technology level "1" coded as class 1.

3.6. Ranking of Key Drivers and Perceived Benefits of Modern Rice Technologies

Thresholds can vary, Landis and Koch (1977) [60] came up with the widely accepted benchmarks for interpreting the strength of agreement. These are:

- **0.00 ≤ w < 0.20**—Slight agreement;
- **0.20 ≤ w < 0.40**—Fair agreement;
- **0.40 ≤ w < 0.60**—Moderate agreement;
- **0.60 ≤ w < 0.80**—Substantial agreement;
- **w ≥ 0.80**—Almost perfect agreement.

The Kendall's W ranking results for Kambia District show a moderate level of agreement among respondents (W = 0.42) regarding the key factors influencing the adoption of modern rice technologies, and the relationship is statistically significant (p = 0.002; χ^2 = 16.79) (Table 7). Among the factors, availability of improved inputs (mean = 3.80) is ranked as the most important factor, followed by the **cost of** modern rice technologies (mean = 4.70), confirming that access and affordability are the primary drivers of adoption [54] [61]. Social and market-related factors such as influence of fellow farmers and market availability (mean = 5.20 each) also rank highly, highlighting the role of peer learning and market access in shaping farmers' decisions [62]. Institutional support through extension services (mean = 5.50) and financial access (credit facilities, mean = 5.60) are moderately influential, while farming experience (mean = 5.30) plays a supportive role [63]. In contrast, expected increase in yield (mean = 6.10), availability of labour (mean = 6.20), and especially level of education (mean = 7.40) are ranked lower, suggesting they are less decisive factors in adoption decisions [64]. Overall, the findings indicate that practical access to inputs, affordability, and social influence are more critical than personal characteristics in determining the uptake of modern rice technologies in the district [65] [66].

Table 7. Kendall's W ranking for major factors influencing adoption of modern rice technologies.

Key Drivers	Kambia	
	Mean	Rank
Cost of modern rice technologies	4.70	2
Expected increase in rice yield	6.10	8
Availability of improved inputs	3.80	1
Access to credit facilities	5.60	7
Level of education	7.40	10
Farming experience	5.30	5
Availability of labour	6.20	9
Advice from extension agents	5.50	6
Influence of fellow farmers	5.20	3
Market availability for rice	5.20	3
p-value	0.002	
Chi-square	16.79	
Kendall's "W"	0.42	

3.7. Relationship between Rice Variety Selection and Household Income Source

The chi-square test of independence result was conducted to examine the association between the type of rice cultivated and the main source of household income. More than half of the expected counts were below 5, and because there is an assumption that no more than 20% of expected counts should be below 5, fisher's exact test for p-value was done to validate chi-square p-value for Kambia District indicate that there is no statistically significant association between the type of rice cultivated and the main source of household income, χ^2 (12, N = 312) = 12.12, p = 0.436, and fisher's p = 0.253 (Table 8). This implies that farmers' choice of rice variety, whether ROK 10, NERICA, traditional, or deep water rice, does not significantly depend on whether their primary income comes from rice farming, livestock, non-farm activities, or other crops. Although the majority of respondents whose main income is rice farming predominantly cultivate ROK 10 and traditional varieties, this pattern is consistent with overall production trends rather than income source differences. Similarly, farmers engaged in non-farm activities or livestock also cultivate a mix of rice types, though in smaller numbers. Overall, the findings suggest that rice variety selection is influenced more by factors such as access to inputs, agro-ecological conditions, and technology availability rather than household income source, highlighting the need to focus on improving input access and extension support rather than targeting farmers based on income categories [67]-[69].

Table 8. Chi-square test on the type of rice cultivated associated with main source of household income.

		Type of Rice Cultivated									
Main Source of Household Income	Class	None	Deepwater Rice	NERICA	ROK 10	Traditional Varieties	df	χ^2	p-value (2-tailed)	Fisher's Exact p-value	Number of Valid Cases
Livestock	Count	0	0	0	2	0	12	12.12	0.436	0.253	2
	Expected	0.03	0.08	0.22	1.1	0.56					
Non-farm activities	Count	1	2	1	5	6					15
	Expected	0.24	0.63	1.68	8.27	4.18					
Other crops	Count	0	0	0	3	0					3
	Expected	0.05	0.13	0.34	1.65	0.84					
Rice farming	Count	4	11	34	162	81					292
	Expected	4.68	12.17	32.76	160.97	81.42					

3.8. Association between Household Income Source and Access to Improved Rice Seed Varieties

The chi-square test of independence results was conducted to examine the association between farmers' main source of household income and their access to improved rice seed varieties. More than half of the expected counts were below 5,

and because there is an assumption that no more than 20% of expected counts should be below 5, fisher's exact test for p-value was done to validate chi-square p-value for Kambia District reveal a strong and statistically significant association between farmers' main source of household income and their access to improved rice seed varieties χ^2 (9, N = 312) = 36.49, p < 0.0001, and fisher's p ≤ 0.0001 (Table 9). This indicates that access to improved seeds varies considerably depending on income sources. Farmers whose primary income is rice farming constitute the largest group with regular access (147 respondents), although a substantial number (109) still report no access, reflecting persistent inequalities even within this group. In contrast, those engaged in non-farm activities show more varied but generally limited access, while farmers relying on livestock or other crops have very small sample sizes but tend to have either regular access or none at all. The significant relationship suggests that income source influences farmers' ability to obtain improved seeds, likely due to differences in financial capacity, market engagement, and institutional support [70] [71]. The findings highlight the need for particularly for farmers with limited or diversified income targeted interventions to improve equitable seed distribution, sources.

Table 9. Chi-square test on the access to improved rice seed varieties associated with main source of household income.

		Access to Improved Rice Seed Varieties								
Main Source of Household Income	Class	No Access	Rarely	Yes, Occasionally	Yes, Regularly	df	χ^2	p-value (2-tailed)	Fisher's Exact p-value	Number of Valid Cases
Livestock	Count	0	0	0	2	9	36.49	<0.0001	<0.0001	2
	Expected	0.71	0.06	0.23	1.01					
Non-farm activities	Count	1	3	6	5					15
	Expected	5.29	0.43	1.73	7.55					
Other crops	Count	0	0	0	3					3
	Expected	1.06	0.09	0.35	1.51					
Rice farming	Count	109	6	30	147					292
	Expected	102.95	8.42	33.69	146.94					

3.9. Post-Hoc Analysis of Access to Improved Rice Seeds by Income Source

The post-hoc test results provide deeper insight into the differences in access to improved rice seed varieties across household income groups. After applying the Bonferroni correction ($\alpha = 0.003125$), only a few pairwise comparisons remain statistically significant (Table 10). Notably, there are significant differences between "Rarely" and non-farm activities (p < 0.001), as well as "Rarely" and rice farming (p < 0.001), indicating that farmers relying on non-farm income or rice farming differ meaningfully in how infrequently they access improved seeds [72] [73]. Similarly, "Yes, occasionally" versus non-farm activities (p < 0.001) shows a

significant difference, suggesting that farmers engaged in non-farm activities have distinct patterns of occasional access compared to other groups. However, most other comparisons, including those involving regular access are not statistically significant after correction, indicating broadly similar patterns across income groups. The findings suggest that while some disparities exist, particularly for limited or occasional access to improved rice seeds is generally uneven but not consistently differentiated across all income sources, pointing to systemic constraints in seed distribution rather than differences driven solely by livelihood type.

Table 10. Post-hoc test on the access to improved rice seed varieties associated with main source of household income.

Post-hoc Test				
Groups	**p-value (Chi-square Test)**	Sig.	**Bonferroni Corrected**	**Alpha**
No access vs Livestock	0.293718113	No	0.003125	0.05
No access vs Non-farm activities	0.017312638	No		
No access vs Other crops	0.200545136	No		
No access vs Rice farming	0.00338962	No		
Rarely vs Livestock	0.810330257	No		
Rarely vs Non-farm activities	4.90727E-05	Yes		
Rarely vs Other crops	0.764177156	No		
Rarely vs Rice farming	0.000808116	Yes		
Yes, occasionally vs Livestock	0.610051462	No		
Yes, occasionally vs Non-farm activities	0.000400127	Yes		
Yes, occasionally vs Other crops	0.528694584	No		
Yes, occasionally vs Rice farming	0.007585125	No		
Yes, regularly vs Livestock	0.158539683	No		
Yes, regularly vs Non-farm activities	0.177015983	No		
Yes, regularly vs Other crops	0.083630275	No		
Yes, regularly vs Rice farming	0.976067053	No		

4. Conclusion and Recommendation

The study examined the factors influencing the adoption of modern rice technologies among farmers in Kambia District, Sierra Leone. The findings showed that rice farming is mainly carried out by experienced smallholder farmers who depend heavily on rice production for their livelihoods and household income. However, low levels of formal education among many farmers may limit their ability to access agricultural information and adopt improved technologies effectively. The study further revealed significant disparities in access to agricultural resources and support services across the selected chiefdoms. Farmers in Robana and Rokupr generally had better access to improved seeds, fertilizers, irrigation, machinery, training, and extension services compared to those in Kasiri and Kychon. Despite the growing use of improved rice varieties such as ROK 10 and NE-

RICA, many farmers still rely on traditional varieties due to inadequate access to inputs, limited financial support, low mechanization, poor irrigation systems, and restricted access to formal credit. Logistic regression analysis identified land ownership, farm size, training on modern rice technologies, and chiefdom location as significant positive factors of adoption. Farmers with larger farms, secure land ownership, and access to training were more likely to adopt modern technologies. In contrast, limited access to credit and extension services negatively affected adoption. The study also found that adoption decisions are strongly influenced by practical and economic factors such as affordability, availability of improved inputs, expected yield increases, institutional support, and market opportunities. The findings further showed that access to improved rice seed varieties was significantly associated with household income source, indicating inequalities in seed access among different farmer groups. Overall, the study concludes that adoption of modern rice technologies in Kambia District is shaped by a combination of economic, institutional, social, and resource-related factors. The study therefore recommends strengthening extension services, improving rural credit access, subsidizing agricultural inputs, expanding farmer training, improving irrigation infrastructure, and ensuring equitable distribution of improved seeds and machinery to enhance technology adoption, food security, and sustainable agricultural development. The study recommends strengthening agricultural extension systems, improving rural credit facilities, subsidizing agricultural inputs, expanding farmer training programs, enhancing irrigation and mechanization infrastructure, and ensuring equitable distribution of improved seed varieties. These interventions are essential for improving rice productivity, household income, food security, and sustainable agricultural development in Kambia District and Sierra Leone as a whole.

5. Limitations of the Study

The study has three main limitations. First, the cross-sectional design captured data at one point in time, limiting the ability to establish causal relationships between resource availability, socio-economic factors, and the adoption of modern rice technologies. Second, the use of purposive sampling in selected rice-producing communities of Kambia District may restrict the generalizability of the findings to other regions of Sierra Leone. Third, the study relied on self-reported data, which may be affected by recall bias, social desirability bias, and subjective perceptions. Despite these limitations, the integration of quantitative survey data and qualitative key informant interviews enhanced the credibility of the findings through methodological triangulation, providing valuable insights into the factors influencing the adoption of modern rice technologies among smallholder farmers in Kambia District.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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