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Resource Availability and Factors Influencing Farmers' Adoption of Modern Rice Technologies in Bonthe District Sierra Leone

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Abstract

Modern rice technologies have the potential to improve productivity and food security among smallholder farmers; however, adoption remains constrained by limited resources and multiple socio-economic factors. This study assessed resource availability and the factors influencing farmers' adoption of modern rice technologies in Bonthe District, Sierra Leone. A quantitative cross-sectional survey design was employed among 325 randomly selected smallholder rice farmers drawn through a multistage sampling procedure from five major rice-producing sections (Borlleh, Madina, Ngepehun, Sogballeh, and Torma). Primary data were collected in February 2026 using a structured interviewer-administered questionnaire. Descriptive statistics summarized respondents' characteristics and resource availability, while Pearson's Chi-square (χ^2) test examined associations between categorical variables. Binary logistic regression identified significant predictors of technology adoption, and Kendall's Coefficient of Concordance (W) assessed agreement in ranking adoption determinants. The findings revealed that farmers generally had limited access to irrigation, agricultural credit, mechanization, and timely farm inputs despite relatively good access to improved rice seed. Logistic regression showed that irrigation availability was the strongest resource-related predictor of adoption (Adjusted OR = 6.23, $p < 0.001$), followed by receipt of training (Adjusted OR

= 4.33, $p < 0.001$), whereas sufficient labour (Adjusted OR = 0.30, $p = 0.031$) and delayed input supply (Adjusted OR = 0.20, $p = 0.024$) significantly reduced adoption. Across all determinants, participation in training and demonstration programmes emerged as the strongest overall predictor (Adjusted OR = 14.35, 95% CI: 5.80 - 35.48, $p < 0.001$), while irrigation availability also exerted a substantial positive influence (Adjusted OR = 10.34, $p < 0.001$). Pearson's χ^2 analysis identified significant associations between resource availability and technology adoption ($p < 0.05$). Kendall's analysis demonstrated strong agreement among respondents regarding adoption determinants ($W = 0.73$, $\chi^2 = 29.20$, $p < 0.0001$), ranking expected rice yield increase, access to credit, and technology cost as the most influential factors. The study concludes that strengthening irrigation infrastructure, farmer training, affordable financing, and timely input delivery will substantially enhance the adoption of modern rice technologies and improve rice productivity in Sierra Leone.

Keywords

Modern Rice Technologies, Technology Adoption, Resource Availability, Logistic Regression, Pearson Chi-Square, Kendall's Coefficient of Concordance, Smallholder Farmers, Sierra Leone

1. Introduction

Global food systems face increasing pressure from rapid population growth, climate change, land degradation, and declining agricultural productivity, particularly in developing countries where agriculture remains the backbone of rural livelihoods [1]-[3]. The Food and Agriculture Organization projects that global food production must increase substantially by 2050 to meet the nutritional demands of a growing population [4]-[6]. Achieving this target requires widespread adoption of modern agricultural technologies capable of increasing productivity while ensuring environmental sustainability. Among staple crops, rice (*Oryza sativa* L.) plays a pivotal role in global food security, providing the primary source of calories for more than half of the world's population and serving as a major source of employment and income for millions of smallholder farmers, particularly in Asia and sub-Saharan Africa [7]-[9].

Modern rice technologies including improved high-yielding and climate-resilient varieties, efficient irrigation systems, mechanization, integrated soil fertility management, improved agronomic practices, and integrated pest management have been widely recognized as effective strategies for increasing rice productivity, reducing production risks, and improving farmers' resilience to climate variability [10]-[12]. Numerous studies have demonstrated that these technologies significantly enhance crop yields, improve resource-use efficiency, and increase farm profitability [13]-[15]. Consequently, governments and development agencies have invested heavily in promoting modern rice production technologies as part of broader strategies to achieve food security, reduce rural poverty, and strengthen agricultural sustainability. Despite the proven benefits of modern rice technologies, their adoption among smallholder farmers remains limited in many developing countries [15] [16]. Adoption is influenced by a combination of economic, institutional, socio-demographic, biophysical, and behavioural factors [17]. In particular, access to key resources such as improved seed, irrigation, credit, machinery, labour, extension services, and timely agricultural inputs, together with farmers' perceptions of costs, expected benefits, market opportunities, and technical training, largely determine adoption decisions. Where these resources and support systems are inadequate, technology uptake remains low despite substantial investments in agricultural development.

In sub-Saharan Africa, rice consumption has increased rapidly over recent decades, outpacing domestic production in many countries [18] [19]. Although governments have introduced numerous initiatives to promote improved rice production technologies, productivity remains considerably lower than global averages because many smallholder farmers continue to rely on traditional production systems characterized by low input use, limited mechanization, inadequate irrigation, and poor access to agricultural support services [20] [21]. Climate change has further intensified these challenges through increased droughts, floods, irregular rainfall patterns, and pest outbreaks, making the adoption of climate-resilient rice technologies increasingly important for sustainable agricultural production [22] [23].

Sierra Leone reflects many of these regional challenges. Agriculture contributes substantially to national employment and rural livelihoods, with rice serving as both the principal staple food and the country's most important food crop [24] [25]. Although successive governments and development partners have implemented programmes promoting improved rice varieties, fertilizer use, mechanization, irrigation development, extension services, and farmer capacity building, national rice production remains insufficient to meet domestic demand, resulting in continued dependence on imports [24] [26]. Limited access to productive resources, weak agricultural infrastructure, inadequate rural financing, climate variability, and uneven extension service delivery continue to constrain farmers' adoption of modern rice technologies and limit productivity gains [27]-[29].

Although previous studies have examined agricultural technology adoption in Sierra Leone and elsewhere, many have focused primarily on socio-economic characteristics or isolated determinants without comprehensively assessing the combined influence of production resources and farmers' perceptions on modern rice technology adoption at the district level. Furthermore, empirical evidence specific to Bonthe District remains limited despite its strategic importance for national rice production and ongoing agricultural development initiatives. Addressing this knowledge gap is necessary to inform evidence-based policies and extension strategies tailored to local production conditions. This study therefore assessed the availability of production resources and examined the factors influencing farmers' adoption of modern rice technologies in Bonthe District, Sierra Leone.

2. Materials and Methods

2.1. Study Area

The study was conducted in Bonthe District, located in the Southern Province of Sierra Leone. The district is one of the country's major rice-producing areas and is characterized by inland valley swamps, mangrove ecosystems, upland rain-fed fields, and floodplains that support diverse rice production systems. Agriculture is the primary livelihood for most households, with rice serving as both a staple food and a major source of income. Five major rice-producing sections Borlleh: 7.551˚N, −11.660˚W, Madina: 8.135˚N, −10.815˚W, Ngepehun: 7.509˚N, −11.650˚W, Sogballeh: 8.018˚N, −11.084˚W, Torma (Torma Bum): 7.416˚N, −12.007˚W were selected because of their high rice production potential.

2.2. Research Design

A mixed-methods research design was employed to investigate resource availability and the factors influencing farmers' adoption of modern rice technologies in Bonthe District, Sierra Leone. The study integrated quantitative and qualitative approaches to provide a comprehensive understanding of technology adoption by examining socioeconomic, institutional, and biophysical factors alongside farmers' perceptions and experiences. This approach enabled the triangulation of findings, thereby enhancing the validity, reliability, and comprehensiveness of the study. The quantitative component adopted a cross-sectional descriptive and analytical survey design, through which data were collected from a representative sample of rice farmers using a structured questionnaire. The qualitative component complemented the survey findings by providing contextual insights into farmers' experiences, perceptions, and challenges, thereby offering a more holistic understanding of the factors influencing technology adoption.

2.3. Sample Size and Sampling Procedure

The study population comprised registered smallholder rice farmers actively engaged in rice cultivation in five major rice-producing sections of Bonthe District: Borlleh, Madina, Ngepehun, Sogballeh, and Torma. Modern rice technologies were defined as improved production methods intended to increase rice productivity, improve resource efficiency, reduce production risks, and enhance climate resilience. These included improved/climate-resilient rice varieties, irrigation, mechanisation, soil-fertility management, improved agronomic practices, and integrated pest management. For the analysis, a farmer was classified as an adopter (1) if he or she used at least one of the specified modern rice technologies during the most recent production season, while farmers who used none were classified as non-adopters (0). The sampling frame consisted of 1,720 registered rice farmers, obtained from the Bonthe District Extension Officer. A multistage sampling technique was employed. First, Bonthe District was purposively selected because of its importance for rice production and the presence of agricultural development interventions. Second, the five major rice-producing sections Borlleh, Madina, Ngepehun, Sogballeh, and Torma—were purposively selected based on production intensity. Finally, eligible farmers were identified from available farmer registers, and respondents were selected using simple random sampling, giving each eligible registered farmer an equal probability of selection and reducing potential sampling bias (**Table 1**). A total of 325 smallholder rice farmers participated in the study. Primary data were collected through face-to-face interviews using a structured interviewer-administered questionnaire in February 2026. The selected farmers were considered appropriate because they were directly involved in rice production and therefore represented potential adopters of modern rice technologies. The sample size was determined using the Yamane [30] formula.

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

where:

n = required sample size;

N = total population size;

e = margin of error (0.05).

For this study:

N = 1,720 farmers;

e = 0.05.

Applying the formula:

$$n = 1720/(1 + 1720\ (0.05^2))$$

$$n = 1720/(1 + 1720\ (0.0025))$$

$$n = 1720/(1 + 4.3)$$

$$n = 1720/5.3$$

$$n = 324.53 \approx 324 \text{ respondents}$$

Table 1. Proportionate distribution of sample size.

SN	Section	Community	Total # of Farmers	Sample Size
1	Torma	Torma	500	94.33
2	Koimato	Borlleh	320	60.37
3	Gbondubu	Madina	300	56.59
4	Fikie	Sogballeh	300	56.59
5	Yagbeh	Ngepehun	300	56.59
	GRAND TOTAL		1,720	324.47 ≈ 325

2.4. Data Collection Procedure

Primary data were collected in February 2026 using both quantitative and qualitative methods. The quantitative data were obtained through a structured interviewer-administered questionnaire adapted from previous agricultural technology adoption studies and contextualized to the study area. The questionnaire comprised sections on respondents' socio-demographic and farm characteristics, the availability and accessibility of agricultural resources (including improved seeds, fertilizers, farm machinery, irrigation facilities, credit, extension services, and markets), factors influencing the adoption of modern rice technologies, farmers' perceptions, and adoption status. It consisted primarily of closed-ended questions with categorical response options to facilitate descriptive and inferential statistical analyses. Face-to-face interviews were conducted by trained enumerators proficient in the local languages at respondents' farms or residences after obtaining informed consent, thereby minimizing the effects of low literacy levels and ensuring the completeness, consistency, and accuracy of the data collected.

The qualitative data were collected through Key Informant Interviews (KIIs) with officials from the Ministry of Agriculture and Food Security, chiefdom authorities, leaders of farmer-based organizations, agro-input dealers, rice cooperative leaders, and representatives of agricultural development projects operating within Bonthe District. These interviews provided in-depth insights into resource availability, institutional support, policy implementation, extension service delivery, and the challenges influencing farmers' adoption of modern rice technologies, complementing and enriching the quantitative findings through triangulation.

2.5. Validity and Reliability of the Instrument

The questionnaire was reviewed by experts in agricultural extension, agricultural economics, and rural development to establish content and face validity. A pilot study involving approximately 10% of the intended sample was conducted outside the study communities to assess clarity, consistency, and appropriateness of the questions. Necessary revisions were made based on feedback before the final survey was administered.

2.6. Data Analysis

Data were entered, cleaned, and analysed using R statistical software. Descriptive statistics, including frequencies and percentages, were used to summarize respondents' characteristics and the availability of agricultural resources. Associations between categorical variables were assessed using the Pearson Chi-square (χ^2) test, with statistical significance set at $p < 0.05$. A binary logistic regression model was used to identify predictors of modern rice technology adoption. The analysis reported Crude Odds Ratios (ORs), Adjusted Odds Ratios (AORs), 95% Confidence Intervals (CIs), Wald statistics, and p-values. Model performance was assessed using the likelihood-ratio chi-square statistic and McFadden's pseudo-R^2. Kendall's Coefficient of Concordance (W) was calculated to assess the level of agreement among respondents in ranking factors influencing technology adoption. Statistical significance was evaluated at $\alpha = 0.05$.

The qualitative component comprised Key Informant Interviews (KIIs) with eight (8) purposively selected informants who had direct knowledge of rice production, agricultural support, extension services, or modern rice technology adoption in Bonthe District. Informants were drawn from the Ministry of Agriculture and Food Security, chiefdom authorities, farmer-based organisations, agro-input dealerships, rice cooperatives, and agricultural development projects. The interview guide focused on (i) the availability and accessibility of agricultural resources and (ii) factors influencing farmers' adoption of modern rice technologies. Following informed consent, interviews were conducted and supplemented with field notes. The qualitative data were analysed using inductive thematic-content analysis, whereby similar responses were coded and grouped into themes and sub-themes concerning resource availability, institutional support, policy implementation, extension service delivery, market access, financial constraints, and technology adoption. The resulting themes were interpreted in relation to the study objectives and compared with the quantitative findings. This triangulation enhanced the credibility and comprehensiveness of the findings by providing contextual explanations for the quantitative patterns observed in the study.

2.7. Ethical Considerations

Ethical approval was obtained from the appropriate institutional authority before commencement of the study. Permission was also secured from local agricultural authorities and community leaders. Participation was voluntary, and informed consent was obtained from all respondents before interviews were conducted. Respondents were assured of confidentiality, anonymity, and the exclusive use of the information for academic research. Personal identifiers were not collected, and participants retained the right to withdraw from the study at any stage without penalty.

3. Results and Discussion

3.1. Demographic Characteristics of the Respondents

The socio-demographic profile of respondents indicates that rice farming in Bonthe District is predominantly practiced by male farmers (62.5%), with the highest male participation recorded in Ngepehun (78.9%), while females were most represented in Borlleh (53.3%) (**Table 2**). Farmers aged 43 - 47 years constituted the largest age group (20.6%), whereas those aged 18 - 22 years represented the smallest proportion (2.2%). Nearly half of the respondents (49.5%) had no formal education, while tertiary education was the least attained level (1.9%). Most farmers had 11 - 15 years of farming experience (23.1%), compared with only 2.2% having 41 - 45 years of experience. Smallholder farming dominated the district, with 2-acre farms being the most common (23.7%), whereas farms of 11, 12, 20, 22, and 25 acres each accounted for only 0.3%. Rice farming was the primary household income source for 88.3% of respondents, while no respondents relied mainly on livestock or non-farm activities. Membership in farmer organizations was almost equally distributed, although Borlleh recorded the highest membership (98.3%) and Sogballeh the lowest (12.3%), highlighting differences in farmers' access to collective support services.

Table 2. Distribution of respondents according to demographic characteristics.

Demographic Characteristics	Bonthe (N = 325)											
	Borlleh		Madina		Ngepehun		Sogballeh		Torma		Total	
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Gender												
Male	28	46.7	39	68.4	45	78.9	42	73.7	49	52.1	203	62.5
Female	32	53.3	18	31.6	12	21.1	15	26.3	45	47.9	122	37.5
Age Group (Years)												
18 - 22	1	1.7	0	0.0	0	0.0	0	0.0	6	6.4	7	2.2
23 - 27	4	6.7	1	1.8	0	0.0	2	3.5	2	2.1	9	2.8
28 - 32	9	15.0	1	1.8	3	5.3	2	3.5	3	3.2	18	5.5
33 - 37	9	15.0	6	10.5	13	22.8	5	8.8	10	10.6	43	13.2
38 - 42	12	20.0	3	5.3	15	26.3	10	17.5	20	21.3	60	18.5
43 - 47	9	15.0	17	29.8	11	19.3	11	19.3	19	20.2	67	20.6
48 - 52	1	1.7	17	29.8	9	15.8	12	21.1	12	28.8	51	15.7
53 - 57	6	10.0	10	17.5	2	3.5	8	14.0	11	11.7	37	11.4
58 - 62	3	5.0	2	3.5	4	7.0	6	10.5	5	5.3	20	6.2
63 - 67	6	10.0	0	0.0	0	0.0	1	1.8	6	6.4	13	4
Education Level												
Quranic	9	15.0	14	24.6	13	22.8	9	15.8	22	23.4	67	20.6
No formal education	41	68.3	23	40.4	28	49.1	34	59.6	35	37.2	161	49.5
Primary	6	10.0	9	15.8	13	22.8	12	21.1	16	17.0	56	17.2
Secondary	4	6.7	9	15.8	3	5.3	2	3.5	17	18.1	35	10.8
Tertiary	0	0.0	2	3.5	0	0.0	0	0.0	4	4.3	6	1.9
Farming experience (Years)												
1 - 5	7	11.7	8	14.0	2	3.5	10	17.5	10	10.6	37	11.4
6 - 10	8	13.3	11	19.3	15	26.3	13	22.8	20	21.3	67	20.6
11 - 15	8	13.3	13	22.8	24	42.1	13	22.8	16	17.0	75	23.1
16 - 20	16	26.7	12	21.1	12	21.1	11	19.3	17	18.1	68	20.9
21 - 30	10	16.7	7	12.3	2	3.5	7	12.3	12	12.8	38	11.7
31 - 35	6	10.0	4	7.0	2	3.5	2	3.5	12	12.8	26	8
36 - 40	4	6.7	0	0.0	0	0.0	1	1.8	3	3.2	8	2.5
41 - 45	1	1.7	2	3.5	0	0.0	0	0.0	4	4.3	7	2.2
Size of rice farm (Acres)												
1	0	0.0	0	0.0	1	1.8	2	3.5	6	6.4	9	2.8
2	32	53.3	3	5.3	8	14.0	5	8.8	29	30.9	77	23.7
3	8	13.3	3	5.3	8	14.0	12	21.1	6	6.4	37	11.4
4	11	18.3	23	40.4	9	15.8	8	14.0	18	19.1	69	21.2

Continued

5	1	1.7	8	14.0	13	22.8	15	26.3	9	9.6	46	14.2
6	5	8.3	9	15.8	7	12.3	7	12.3	6	6.4	34	10.5
7	0	0.0	0	0.0	4	7.0	1	1.8	2	2.1	7	2.1
8	F0	0.0	7	12.3	5	8.8	4	7.0	5	5.3	21	6.5
9	0	0.0	0	0.0	2	3.5	1	1.8	0	0.0	3	0.9
10	3	5.0	1	1.8	0	0.0	1	1.8	8	8.5	13	4
11	0	0.0	0	0.0	0	0.0	0	0.0	1	1.1	1	0.3
12	0	0.0	0	0.0	0	0.0	0	0.0	1	1.1	1	0.3
15	0	0.0	2	3.5	0	0.0	0	0.0	2	2.1	4	1.2
20	0	0.0	0	0.0	0	0.0	1	1.8	0	0.0	1	0.3
22	0	0.0	0	0.0	0	0.0	0	0.0	1	1.1	1	0.3
25	0	0.0	1	1.8	0	0.0	0	0.0	0	0.0	1	0.3
Main source of household												
Rice farming	58	96.7	57	100.0	43	75.4	40	70.2	89	94.7	287	88.3
Other crops	2	3.3	0	0.0	14	24.6	17	29.8	5	5.3	38	11.7
Livestock	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Non-farm activities	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0
Member of farmer organization												
Yes	59	98.3	33	57.9	16	28.1	7	12.3	46	48.9	161	49.5
No	1	1.7	24	42.1	41	71.9	50	87.7	48	51.1	164	50.5

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

The distribution of respondents' access to resources for adopting modern rice technologies reveals substantial variations across the study communities. NERICA was the most widely cultivated improved rice variety, accounting for 35.1% of respondents, with the highest adoption observed in Madina (89.5%) (**Table 3**) [31] [32]. In contrast, traditional rice varieties were predominantly cultivated in Sogballeh (80.7%), while only 1.9% of respondents reported cultivating no specific rice variety. Access to improved rice seed varieties was generally favorable, with 38.8% reporting regular access and 33.2% having occasional access [33] [34]. However, 19.1% of respondents reported no access to improved seeds, with Sogballeh exhibiting the greatest constraint (94.7%).

Regarding fertilizer availability, 40.6% of respondents indicated that fertilizers were sometimes available, making it the most common response, while 23.7% reported that fertilizers were not available. Sogballeh experienced the greatest limitation, with 94.7% indicating no fertilizer availability. Access to farm machinery was largely facilitated through cooperatives, accounting for 50.2% of respondents, while only 1.8% owned machinery [35] [36]. Conversely, 28.3% reported having no access to machinery, particularly in Sogballeh (75.4%) and Ngepehun (63.2%), highlighting significant mechanization constraints.

Irrigation water availability was generally limited, as 46.5% of respondents relied entirely on rain-fed farming and reported no irrigation access [37]. Only 25.8% had irrigation water available throughout the growing season, with Madina recording the highest availability (91.2%). Personal savings were the dominant source of finance for rice production, used by 75.4% of respondents, whereas government support represented the least common financing source (2.1%) [38] [39]. Access to agricultural credit was also limited, with 46.5% reporting that credit was never available when needed, compared to only 14.5% who indicated that credit was always available [40].

Labour availability presented another challenge, as the largest proportion of respondents (34.5%) reported that labour was rarely sufficient during peak farming periods, while 29.2% considered labour always sufficient [41] [42]. Land tenure was dominated by communal or family ownership (34.5%) and fully owned land (32.0%), whereas leased land was the least common arrangement (1.2%) [43]. The timely availability of farm inputs varied considerably, with nearly half of respondents (48.9%) indicating that inputs were often available with only minor delays. However, one-fifth (20.0%) reported that inputs were not available on time, particularly in Sogballeh where 91.2% experienced delays.

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

Access to Available Resources	Bonthe (N = 325)											
	Borlleh		Madina		Ngepehun		Sogballeh		Torma		Total	
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Type of rice cultivated												
ROK 10	30	50.0	0	0.0	16	28.1	0	0.0	22	23.4	68	20.9
NERICA	0	0.0	51	89.5	28	49.1	1	1.8	34	36.2	114	35.1
Traditional Varieties	0	0.0	0	0.0	4	7.0	46	80.7	7	7.4	57	17.5
Deepwater Rice	30	50.0	6	10.5	6	10.5	9	15.8	29	30.9	80	24.6
None	0	0.0	0	0.0	3	5.3	1	1.8	2	2.1	6	1.9
Access to improved rice seed varieties												
Yes, Regularly	28	46.7	31	54.4	18	31.6	0	0.0	49	52.1	126	38.8
Yes, occasionally	31	51.7	26	45.6	12	21.1	3	5.3	36	38.3	108	33.2
Rarely	1	1.7	0	0.0	21	36.8	0	0.0	7	7.4	29	8.9
No access	0	0.0	0	0.0	6	10.5	54	94.7	2	2.1	62	19.1
Access to chemical fertilizers for rice production												
Always available when needed	18	30.0	26	45.6	0	0.0	0	0.0	17	18.1	61	18.8
Sometimes available	36	60.0	30	52.6	15	26.3	2	3.5	49	52.1	132	40.6

Continued

Rarely available	6	10.0	1	1.8	31	54.4	1	1.8	16	17.0	55	16.9
Not available	0	0.0	0	0.0	11	19.3	54	94.7	12	12.8	77	23.7
Level of access to farm machinery (tractor, power tiller, thresher)												
Own machinery	0	0.0	4	7.0	0	0.0	0	0.0	2	2.1	6	1.8
Rent/borrow machinery	0	0.0	26	45.6	6	10.5	13	22.8	19	20.2	64	19.7
Access through cooperative	56	93.3	27	47.4	15	26.3	1	1.8	64	68.1	163	50.2
No access to machinery	4	6.7	0	0.0	36	63.2	43	75.4	9	9.6	92	28.3
Level of irrigation water availability for your rice farm												
Available throughout the growing season	0	0.0	52	91.2	2	3.5	1	1.8	29	30.9	84	25.8
Available only part of the season	26	43.3	5	8.8	27	47.4	0	0.0	23	24.5	81	24.9
Rarely available	2	3.3	0	0.0	1	1.8	0	0.0	6	6.4	9	2.8
Not available (rain-fed only)	32	53.3	0	0.0	27	47.4	56	98.2	36	38.3	151	46.5
Main source of finance for rice farming												
Personal savings	55	91.7	45	78.9	25	43.9	55	96.5	65	69.1	245	75.4
Bank loan	0	0.0	3	5.3	2	3.5	0	0.0	3	3.2	8	2.5
Microfinance institution	0	0.0	5	8.8	1	1.8	0	0.0	7	7.4	13	4.0
Farmer cooperative	3	5.0	3	5.3	1	1.8	1	1.8	10	10.6	18	5.5
Friends or relatives	1	1.7	0	0.0	26	45.6	1	1.8	6	6.4	34	10.5
Government support/subsidy	1	1.7	1	1.8	2	3.5	0	0.0	3	3.2	7	2.1
Training on modern rice technologies												
Yes, formal training	55	91.7	45	78.9	25	43.9	55	96.5	65	69.1	245	75.4
Yes, informal training	0	0.0	3	5.3	2	3.5	0	0.0	3	3.2	8	2.5
Yes, both formal and informal	0	0.0	5	8.8	1	1.8	0	0.0	7	7.4	13	4.0
No training received	3	5.0	3	5.3	1	1.8	1	1.8	10	10.6	18	5.5
Little Training (informal)	1	1.7	0	0.0	26	45.6	1	1.8	6	6.4	34	10.5
Little training (formal)	1	1.7	1	1.8	2	3.5	0	0.0	3	3.2	7	2.1
Access to agricultural credit when needed												
Always available	15	25.0	19	33.3	0	0.0	0	0.0	13	13.8	47	14.5
Often available	6	10.0	13	22.8	4	7.0	0	0.0	19	20.2	42	12.9
Sometimes available	5	8.3	22	38.6	27	47.4	2	3.5	29	30.9	85	26.2
Never available	34	56.7	3	5.3	26	45.6	55	96.5	33	35.1	151	46.5
Labour readily available during peak farming periods												
Always sufficient	31	51.7	26	45.6	1	1.8	5	8.8	32	34.0	95	29.2

Continued

Sometimes sufficient	8	13.3	31	54.4	9	15.8	4	7.0	33	35.1	85	26.2
Rarely sufficient	21	35.0	0	0.0	36	63.2	32	56.1	23	24.5	112	34.5
Not available	0	0.0	0	0.0	11	19.3	16	28.1	6	6.4	33	10.2
Land ownership for rice farming												
Fully owned	9	15.0	30	52.6	20	35.1	0	0.0	45	47.9	104	32.0
Rented	0	0.0	23	40.4	3	5.3	56	98.2	20	21.3	102	31.4
Leased	0	0.0	1	1.8	0	0.0	0	0.0	3	3.2	4	1.2
Communal/family land	51	85.0	2	3.5	34	59.6	1	1.8	24	25.5	112	34.5
Sharecropping	0	0.0	1	1.8	0	0.0	0	0.0	2	2.1	3	0.9
Farm inputs availability on time in locality												
Always available on time	1	1.7	11	19.3	17	29.8	1	1.8	11	11.7	41	12.6
Often available with minor delays	44	73.3	46	80.7	7	12.3	1	1.8	61	64.9	159	48.9
Rarely available on time	15	25.0	0	0.0	24	42.1	3	5.3	18	19.1	60	18.5
Not available on time	0	0.0	0	0.0	9	15.8	52	91.2	4	4.3	65	20.0

3.3. Logistic Regression of Adoption on Available Resources

The logistic regression model showed a good overall fit, with the section-adjusted model explaining 54.1% of the variation in adoption (McFadden $R^2 = 0.541$) and a significant likelihood ratio statistic (LR $\chi^2 = 238.9$, df = 14), (**Table 4**) indicating that available resources collectively influenced farmers' adoption of modern rice technologies [44] [45].

Among the predictors, irrigation availability was the strongest positive determinant of adoption, with the highest odds ratio (OR = 10.34, Adjusted OR = 6.23, $p < 0.001$) and the largest Wald statistic (34.00) (**Table 4**). This indicates that farmers with access to irrigation were significantly more likely to adopt modern rice technologies than those without irrigation [46] [47]. Receiving training was the second most influential factor (OR = 6.48, Adjusted OR = 4.33, $p < 0.001$), (**Table 4**) demonstrating that farmer capacity building and extension support substantially increased the likelihood of technology adoption [48].

Conversely, access to machinery was the least influential positive variable (OR = 1.17, Wald = 0.09, $p = 0.769$), (**Table 4**) indicating no significant effect on adoption. Similarly, access to fertilizer (OR = 1.25, $p = 0.686$) and access to improved seed (OR = 2.23, $p = 0.259$) (**Table 4**) were not statistically significant predictors. Among the negative predictors, sufficient labour showed the strongest significant negative association with adoption (OR = 0.29, Adjusted OR = 0.30, $p = 0.031$), suggesting that farmers with adequate labour were less likely to adopt modern technologies, possibly because they continued relying on traditional labour-intensive practices [49]. Timely input supply also showed a significant negative effect after adjustment (Adjusted OR = 0.20, $p = 0.024$), whereas full land ownership had a weak and non-significant influence (OR = 0.73, $p = 0.392$).

Table 4. Logistic regression of modern rice technology adoption on available resources: crude and section-adjusted models.

Predictor	B	SE	OR	z	Wald	df	p	Adj. OR (p)[1]
Access to improved seed	0.80	0.71	**2.23**	1.13	1.27	1	0.259	1.23 (0.810)
Access to fertilizer	0.22	0.55	**1.25**	0.40	0.16	1	0.686	1.15 (0.810)
Access to machinery	0.16	0.54	**1.17**	0.29	0.09	1	0.769	1.96 (0.377)
Irrigation available	2.34	0.40	**10.34**	5.83	34.00	1	<0.001	6.23 (<0.001)
Formal finance source	0.40	0.51	**1.49**	0.78	0.62	1	0.433	1.45 (0.470)
Received training	1.87	0.40	**6.48**	4.67	21.82	1	<0.001	4.33 (<0.001)
Access to credit	0.34	0.41	**1.40**	0.82	0.67	1	0.414	0.80 (0.617)
Sufficient labour	−1.25	0.52	**0.29**	−2.41	5.79	1	0.016	0.30 (0.031)
Owns land (fully)	−0.31	0.36	**0.73**	−0.86	0.73	1	0.392	0.54 (0.099)
Timely input supply	−1.11	0.64	**0.33**	−1.74	3.03	1	0.082	0.20 (0.024)

Model fit: unadjusted LR chi-square = 201.0 (df = 10), McFadden R-square = 0.455; section-adjusted LR chi-square = 238.9 (df = 14), McFadden R-square = 0.541. n = 325; adopters = 182. Coding of binary predictors: Unless otherwise stated, binary predictors were coded 1 = condition present/Yes and 0 = condition absent/No, with the 0 category serving as the reference group. Thus, the odds ratios represent the odds of technology adoption among farmers with the specified condition relative to those without it. Note. B = penalized log-odds coefficient; OR = odds ratio; Wald = squared z statistic. Predictors are binary (1 = condition present). Adj. OR (p) is the odds ratio from the section-adjusted model. $p < 0.05$, $p < 0.01$, $p < 0.001$.

The Key Informant Interviews indicated that although rice farmers had access to resources such as financial support, improved seeds, fertilizers, machinery, extension services, and institutional assistance, access remained uneven. Financial constraints were the primary barrier to adopting modern rice technologies, followed by inadequate machinery, irrigation, improved seeds, and extension services. Membership in farmer organizations enhanced access to resources, training, and financial support, while small-scale and low-income farmers faced greater challenges in accessing these resources, limiting their adoption of modern rice technologies.

3.4. Major Factors Influencing Adoption of Modern Rice Technologies

The results indicate that "Technology cost was one of the most strongly perceived determinants of adoption, with 81.2% of farmers rating its influence as strong or very strong and an additional 33.8% indicating a strong influence, meaning that over four-fifths (81.2%) of respondents regarded cost as a major factor in their adoption decisions (**Table 5**) [50] [51]. However, the Kendall's W ranking provided a different ordering of determinants, with expected increase in rice yield ranked first, access to credit second, and technology cost third. These findings indicate that perceived strength and relative rank are distinct measures and should therefore not be interpreted as equivalent". Similarly, the expected increase in rice yield was another key determinant, with 44.9% reporting a very strong influence and 42.2% reporting a strong influence, demonstrating that farmers were highly motivated to adopt technologies that promised higher productivity [52] [53]. Other important determinants included market availability for rice (36.9% very strong; 36.3% strong), farming experience (35.4% very strong; 37.5% strong), and availability of improved inputs (36.0% very strong; 41.8% strong), highlighting the importance of economic incentives, production resources, and farming knowledge in technology adoption [54].

In contrast, level of education emerged as the least influential determinant. Only 17.9% of respondents perceived education as having a very strong influence, while 23.4% considered it to have a low influence and 17.5% reported no influence, making it the variable with the lowest perceived impact on adoption decisions [55] [56]. Likewise, extension agents' influence recorded the lowest proportion of respondents indicating a very strong influence (18.8%), although 43.4% still rated their influence as strong, suggesting that extension services played more of a supportive than a primary role [57].

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

Major Determinants	Bonthe (N = 325)											
	Borlleh		Madina		Ngepehun		Sogballeh		Torma		Total	
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%
Cost of modern rice technologies												
Very strong influence	31	51.7	2	3.5	32	56.1	49	86.0	40	42.6	154	47.4
Strong influence	9	15.0	55	96.5	4	7.0	3	5.3	39	41.5	110	33.8
Moderate influence	16	26.7	0	0.0	9	15.8	3	5.3	9	9.6	37	11.4
Low influence	2	3.3	0	0.0	9	15.8	1	1.8	4	4.3	16	4.9
No influence	2	3.3	0	0.0	3	5.3	1	1.8	2	2.1	8	2.5
Expected increase in rice yield												
Very strong influence	34	56.7	2	3.5	24	42.1	44	77.2	42	44.7	146	44.9
Strong influence	13	21.7	53	93.0	14	24.6	12	21.1	45	47.9	137	42.2
Moderate influence	10	16.7	2	3.5	11	19.3	0	0.0	6	6.4	29	8.9
Low influence	3	5.0	0	0.0	8	14.0	1	1.8	1	1.1	13	4.00
No influence	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0
Availability of improved inputs												
Very strong influence	33	55.0	3	5.3	17	29.8	29	50.9	35	37.2	117	36.0
Strong influence	14	23.3	48	84.2	19	33.3	6	10.5	49	52.1	136	41.8
Moderate influence	10	16.7	6	10.5	9	15.8	2	3.5	8	8.5	35	10.8
Low influence	2	3.3	0	0.0	8	14.0	4	7.0	0	0.0	14	4.3
No influence	1	1.7	0	0.0	4	7.0	16	28.1	2	2.1	23	7.1
Access to credit facilities												

Continued

Very strong influence	28	46.7	1	1.8	20	35.1	28	49.1	37	39.4	114	35.1
Strong influence	9	15.0	26	45.6	14	24.6	14	24.6	46	48.9	109	33.5
Moderate influence	15	25.0	6	10.5	11	19.3	5	8.8	4	4.3	41	12.6
Low influence	6	10.0	22	38.6	8	14.0	2	3.5	6	6.4	44	13.5
No influence	2	3.3	2	3.5	4	7.0	8	14.0	1	1.1	17	5.2
Level of education												
Very strong influence	21	35.0	0	0.0	9	15.8	10	17.5	18	19.1	58	17.9
Strong influence	9	15.0	2	3.5	7	12.3	14	24.6	34	36.2	66	20.3
Moderate influence	21	35.0	1	1.8	18	31.6	13	22.8	15	16.0	68	20.9
Low influence	6	10.0	28	49.1	20	35.1	4	7.0	18	19.1	76	23.4
No influence	3	5.0	26	45.6	3	5.3	16	28.1	9	9.6	57	17.5
Farming experience												
Very strong influence	30	50.0	1	1.8	20	35.1	32	56.1	32	34.0	115	35.4
Strong influence	12	20.0	27	47.4	13	22.8	21	36.8	49	52.1	122	37.5
Moderate influence	15	25.0	11	19.3	11	19.3	4	7.0	8	8.5	49	15.1
Low influence	3	5.0	18	31.6	10	17.5	0	0.0	4	4.3	35	10.8
No influence	0	0.0	0	0.0	3	5.3	0	0.0	1	1.1	4	1.2
Availability of labour												
Very strong influence	25	41.7	4	7.0	6	10.5	19	33.3	30	31.9	84	25.8
Strong influence	15	25.0	23	40.4	14	24.6	21	36.8	43	45.7	116	35.7
Moderate influence	18	30.0	2	3.5	20	35.1	9	15.8	12	12.8	61	18.8
Low influence	2	3.3	28	49.1	14	24.6	6	10.5	8	8.5	58	17.8
No influence	0	0.0	0	0.0	3	5.3	2	3.5	1	1.1	6	1.9
Extension agents influence on decision												
Very strong influence	17	28.3	0	0.0	4	7.0	12	21.1	28	29.8	61	18.8
Strong influence	26	43.3	48	84.2	10	17.5	8	14.0	49	52.1	141	43.4
Moderate influence	11	18.3	4	7.0	26	45.6	9	15.8	8	8.5	58	17.8
Low influence	6	10.0	5	8.8	12	21.1	7	12.3	6	6.4	36	11.1
No influence	0	0.0	0	0.0	5	8.8	21	36.8	3	3.2	29	8.9
Fellow farmers												
Very strong influence	28	46.7	1	1.8	5	8.8	21	36.8	26	27.7	81	24.9
Strong influence	29	48.3	28	49.1	7	12.3	19	33.3	43	45.7	126	38.8
Moderate influence	2	3.3	1	1.8	19	33.3	11	19.3	13	13.8	46	14.2
Low influence	1	1.7	27	47.4	22	38.6	6	10.5	11	11.7	67	20.6
No influence	0	0.0	0	0.0	4	7.0	0	0.0	1	1.1	5	1.5
Market availability for rice												
Very strong influence	28	46.7	4	7.0	21	36.8	30	52.6	37	39.4	120	36.9

Continued

Strong influence	15	25.0	34	59.6	13	22.8	13	22.8	43	45.7	118	36.3
Moderate influence	15	25.0	4	7.0	10	17.5	4	7.0	8	8.5	41	12.6
Low influence	2	3.3	15	26.3	13	22.8	10	17.5	6	6.4	46	14.2
No influence	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0

3.5. Logistic Regression of Factors of Modern Rice Technology Adoption

The logistic regression results identified attendance at training and demonstration programmes as the strongest determinant of modern rice technology adoption, with farmers who participated being over 14 times more likely to adopt modern technologies (OR = 14.35, 95% CI: 5.80 - 35.48, $p < 0.001$) (**Table 6**), which represents a separate thematic/domain-specific analysis with a different covariate structure. This was followed by availability of irrigation (Adjusted OR = 10.34, 95% CI: 4.72 - 22.68, $p < 0.001$) and receipt of training (Adjusted OR = 6.48, 95% CI: 2.96 - 14.20, $p < 0.001$), (**Table 6**) demonstrating that access to extension services, technical knowledge, and reliable water supply were the most important factors promoting adoption [58]. Among the perception-related variables, perceived environmental harm also significantly increased adoption (Adjusted OR = 1.92, $p < 0.001$), suggesting that farmers who recognized environmental challenges were more willing to adopt improved technologies [59].

Conversely, strong extension influence showed the strongest negative association with adoption (Adjusted OR = 0.07, 95% CI: 0.02 - 0.23, $p < 0.001$), (**Table 6**) making it the least favourable predictor in the model. Other factors that significantly reduced adoption included sufficient labour (Adjusted OR = 0.29, $p = 0.016$), loam soil (Adjusted OR = 0.37, $p = 0.003$), perceived yield benefit (Adjusted OR = 0.46, $p = 0.022$), and perceived income increase (Adjusted OR = 0.52, $p = 0.001$) (**Table 6**). Additional barriers such as extension-support constraints, credit-access limitations, and crop-failure risk also significantly reduced the likelihood of adoption [60] [61].

Table 6. Logistic regression of determinants of modern rice technology adoption.

Thematic domain	Determinant	OR (95% CI)	p	Direction of effect
Biophysical	Drought exposure	**3.00 (1.70 - 5.28)**	<0.001	Increases adoption
Biophysical	Loam soil	**0.37 (0.19 - 0.71)**	0.003	Reduces adoption
Extension	Attended training/demo	**14.35 (5.80 - 35.48)**	<0.001	Increases adoption
Extension	Strong extension influence	**0.07 (0.02 - 0.23)**	<0.001	Reduces adoption
Perceptions	Yield benefit	**0.46 (0.23 - 0.89)**	0.022	Reduces adoption
Perceptions	Income increase	**0.52 (0.35 - 0.78)**	0.001	Reduces adoption
Perceptions	Environmental harm	**1.92 (1.52 - 2.41)**	<0.001	Increases adoption
Perceptions	Extension-support barrier	**0.57 (0.40 - 0.81)**	0.002	Reduces adoption

Continued

Perceptions	Credit-access barrier	**0.63 (0.43 - 0.93)**	0.020	Reduces adoption
Perceptions	Crop-failure risk	**0.75 (0.60 - 0.93)**	0.008	Reduces adoption
Resources	Irrigation available	**10.34 (4.72 - 22.68)**	<0.001	Increases adoption
Resources	Received training	**6.48 (2.96 - 14.20)**	<0.001	Increases adoption
Resources	Sufficient labour	**0.29 (0.10 - 0.79)**	0.016	Reduces adoption

Note. OR = odds ratio; CI = confidence interval. Estimates are Firth penalized odds ratios from the section-adjusted thematic models; only predictors significant at $p < 0.05$ in the unadjusted models are listed. $p < 0.05$, $p < 0.01$, $p < 0.001$.

3.6. Kendall's W Ranking for Major Factors Influencing Adoption of Modern Rice Technologies

The Kendall's coefficient of concordance showed that respondents had a strong and statistically significant agreement in ranking the major determinants of modern rice technology adoption ($W = 0.73$, $\chi^2 = 29.20$, $p < 0.0001$) (Table 7). Expected increase in rice yield was ranked as the most important determinant, followed by access to credit facilities and cost of modern rice technologies, while advice from extension agents was ranked as the least influential factor [62] [63].

Similarly, the ranking of farmers' perceptions showed that the positive effects of modern technologies on rice yield and rice quality were the highest-ranked drivers, whereas the perception that modern technologies involve high financial risk was the lowest-ranked barrier [64]. Although the level of agreement was moderate ($W = 0.38$), it remained statistically significant ($p < 0.01$), indicating that respondents shared a moderate consensus regarding the perceived drivers and barriers.

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

Key Drivers	Bonthe	
	Mean	Rank
Cost of Modern Rice Technologies	5.00	3
Expected Increase in Rice Yield	4.30	1
Availability of Improved Inputs	5.40	6
Access to Credit Facilities	4.90	2
Level of Education	6.40	9
Farming Experience	5.20	4
Availability of Labour	6.00	8
Advice from Extension Agents	6.80	10
Influence of Fellow Farmers	5.80	7
Market Availability for Rice	5.20	4
p-value	<0.0001	
Chi-Square	29.20	
Kendall's "W"	0.73	

The Key Informant Interviews revealed that farmers' adoption of modern rice technologies was primarily influenced by education, extension services, demonstration trials, affordable inputs, improved seeds, mechanization, access to credit, farm size, income, and agricultural support programmes. Affordable inputs, access to credit, and expected economic returns promoted adoption, whereas high costs and limited financing constrained technology uptake. Extension activities, particularly demonstration trials, training, farm visits, and awareness campaigns, were identified as essential in improving farmers' knowledge and encouraging the adoption of modern rice technologies.

4. Conclusion and Recommendations

This study established that the adoption of modern rice technologies among smallholder farmers in Bonthe District is largely determined by the availability of production resources and institutional support. While access to improved rice seed was relatively good, limited irrigation, agricultural credit, mechanization, labour availability, and timely input supply constrained adoption. Irrigation and farmer training emerged as the strongest predictors of adoption, whereas labour shortages and delayed input delivery significantly reduced adoption. Farmers also ranked expected yield increase, access to credit, and technology cost as the most influential determinants. Therefore, the Government of Sierra Leone should prioritize investment in small-scale irrigation, strengthen extension and demonstration programmes, expand affordable agricultural credit through financial institutions and cooperatives, and improve timely input distribution. Mechanization support through cooperative ownership and subsidized equipment should also be promoted. Future studies should employ longitudinal and mixed-method approaches to evaluate long-term technology adoption and its effects on productivity, household income, and food security.

Author Contributions

Conceptualization, Prince Tongor Mabey, Patrick Amara Ngaojia, methodology, Daphne Sia Shirley Roy-Johnson, and Jonathan Sahr Kpakima; formal analysis, Jusufu Abdulai, and Osman Musa Kalokoh; investigation, Musu Monica Lansana, and Ishmail Kakpindi Kaifala.; resources, X.X.; data curation, Patrick Amara Ngaojia, Daphne Sia Shirley Roy-Johnson, and Jonathan Sahr Kpakima; writing—original draft preparation, Prince Tongor Mabey, Patrick Amara Ngaojia, and Daphne Sia Shirley Roy-Johnson; writing—review and editing, Prince Tongor Mabey, Jonathan Sahr Kpakima, and Jusufu Abdulai; supervision, Prince Tongor Mabey, Michaelson Maada Mawondeh, Saidu Bah and Patrick Amara Ngaojia.; funding acquisition, Michaelson Maada Mawondeh, and Saidu Bah. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

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

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