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Research Article

Cultivation of Local Rice Varieties in Bangladesh: Assessing the Farm Level Determinants

Md Saiful Islam, Mohammad Chhiddikur Rahman✉, Md Enamul Haque, Md Shajedur Rahaman, Md Imran Omar, Md Abdur Rouf Sarkar and Mohammad Ariful Islam

Agricultural Economics Division, Bangladesh Rice Research Institute, Bangladesh

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Correspondence
Mohammad Chhiddikur Rahman
✉: siddiquer07@gmail.com

Abstract

One of the main objectives of the green revolution is to replace the local (traditional) cultivars with high-yielding varieties (HYVs). Replacing HYVs in the local cultivars-intensive areas would increase rice production and strengthen national food security. To do this, it is necessary to identify the determinants of cultivating local rice varieties by farmers. Therefore, this study used fractional logistic regression in the popular Aman and Boro season local rice variety-intensive areas to find out the causes of cultivating local rice varieties. The findings reveal that the main cause is the adverse ecology, where HYVs are not suitable, but local cultivars have physiological attributes to be well suited. The local cultivars are growing mainly in the *Haor* and flood-prone ecosystems, where modern varieties can not be sustained. The profitability of local rice cultivars is better than the HYVs as well. Moreover, farmers' socioeconomic conditions such as age, education, occupation, income, and farm size influence the cultivation of local rice varieties. The yield, land topography, and market price also have an impact on the adoption intensity of local cultivars. The farmers also opined that the special grain quality of the local rice cultivars attracts the farmers, consumers, and market price that lubricate the intensity of local rice varieties adoption in the specific areas of Bangladesh. The findings of this study would be helpful for the rice breeders, scientists, and policymakers to develop suitable modern rice cultivars and management packages for boosting rice production in the targeted local rice cultivars intensive areas of Bangladesh.

Introduction

Rice is well cultivated in Bangladesh as the agroclimatic conditions are ideal for cultivating rice throughout the year covering three different seasons- Aus, Aman, and Boro (Rahaman et al., 2022; Shelley et al., 2016; Aziz et al., 2022). The country's population is continuously expanding, putting a strain on scarce agricultural land (Yeasmin et al., 2020). The majority of productive land has already been involved in cultivation. Moreover, arable land is declining with time due to the rising demand for residential and industrial use (Kabir et al., 2020). Natural calamities such as droughts, floods, and cyclones strike Bangladesh regularly (Rahman et al., 2021a; Rahman et al., 2022a). Flooding and salinization of farmlands are expected to grow as a result of climate change and sea-level rise, especially near the southern coast (Mainuddin et al., 2021). Moreover, Bangladesh's rice sector faces market and environmental risks (Kabir et al., 2021; Rahman et al., 2020). These factors have jeopardized the food security dilemma of feeding an ever-increasing future population. Rice is the most significant crop in Bangladesh, occupying roughly 78% of total agricultural land (Rahaman et al., 2020; Islam et al., 2019; Sarkar et al., 2022; Rahman et al., 2022b; Rahman et al., 2023). It is the country's principal food source for approximately 170 million people. Rice production is thus critical to Bangladesh's political economy (Rahman et al., 2020). Through evolved initiatives such as expanding the area under cultivation, increasing cropping intensity, incorporating of high yielding varieties, considerably high usage of chemical fertilizers and pesticides, enhancing irrigation supply, and upgrading farm equipment and crop protection systems, the green revolution resulted in high agricultural production (John and Babu, 2021). Despite having more than 8,500 rice germplasm (Islam et al., 2018), during the Green Revolution, Bangladesh was offered high-yielding cultivars

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manufactured in laboratories and bundled with inorganic fertilizers, pesticides, groundwater, etc (Rahman et al., 2021b). The next phase is the establishment of hybrid rice.

To meet the ever-growing demand, Bangladesh Rice Research Institute (BRRI) and other research institutes and agricultural universities have accepted the challenges of the green revolution and developed modern and high-yielding rice varieties (HYVs), hybrids, and improved management packages targeting the favorable and stress-prone areas to boost the rice production (Mottaleb et al., 2015; Shelley et al., 2016). Through the hard work of extension personnel, the adoption of modern varieties has increased on average by 4.92% whereas the adoption of local rice varieties has decreased on average by 4.50% annually during the 1971-2019 period (Rahman et al., 2021a).

The yield of local rice cultivars is much lower than the HYVs in Bangladesh (Figure 1). The adoption rate of local rice varieties is 7.74%, 13.61%, and 0.48% in the Aus, Aman, and Boro seasons, respectively (Table 1). The experts assume that the replacement of existing local rice varieties with suitable HYVs would enhance the overall yield and national rice production of Bangladesh could produce enough rice to feed the country for one month if the existing local varieties could be replaced with MVs. The local rice varieties are cultivated in the specific stress-prone areas of Bangladesh, because of their stress-averse ability and physiological characteristics (Shelley et al., 2016). More than 1000 local rice varieties are being cultivated in Bangladesh, most of which are used to adapt to climate events (Kamruzzaman et al., 2017). To replace the local rice cultivars with HYVs, it is important to identify the determinants of cultivating local rice varieties in Bangladesh. Therefore, this study has been designed to identify the farm-level determinants, and consequences of cultivating popular local rice varieties in Bangladesh from the socioeconomic viewpoint. As the cases, this study considered popular local varieties '*Biroi*', '*Gainja*', and '*Gainda*' for the Aman season and '*Rata boro*' and '*Tepi boro*' for the Boro season. The study compares the profitability and input use pattern of these popular local and HYV rice varieties and also identifies the reasons for cultivating these local rice varieties in the respective study areas. The findings of this study would help policymakers and rice scientists to develop modern rice varieties and cultivation packages to boost rice production in the local rice varieties intensive areas.

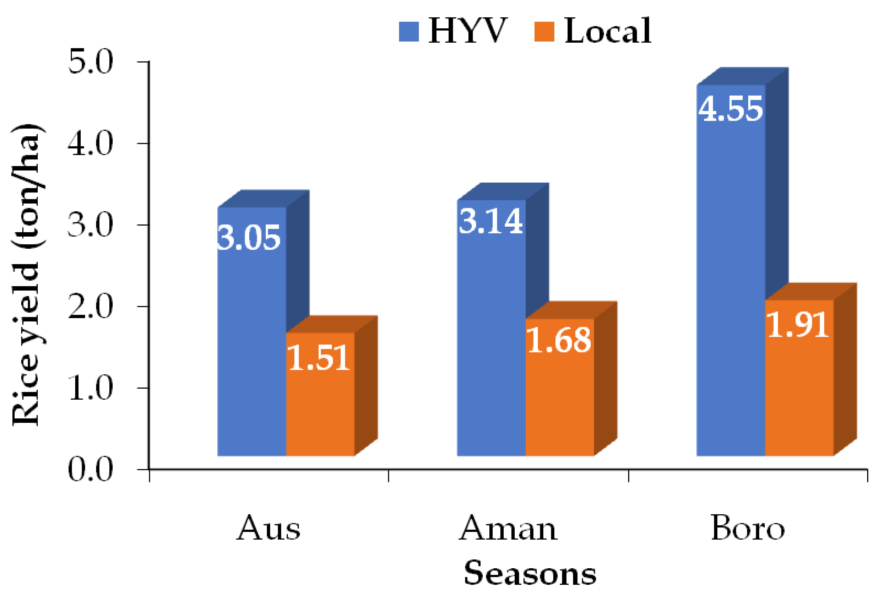


Figure 1. Yield scenario of HYV and local rice varieties in Bangladesh during 2020-21.
Data source: Department of Agricultural Extension (DAE).

Table 1. Area and production share of different rice growing seasons in Bangladesh

Season	Adoption rate (%)		Production share (%)		Total area and production	
	Local	MV	Local	MV	Area (Million ha)	Production (Million tons)
Aus	7.74	92.26	4.18	95.82	1.30	3.68
Aman	13.61	86.39	8.00	92.00	5.54	15.42
Boro	0.48	99.52	0.21	99.79	4.88	20.97

Note: Authors' estimation based on the data from DAE during 2020-21.

Materials and Methods

Study area and data

This study employed a multi-stage sampling technique to collect data from the local rice-growing farmers. We purposively selected five districts of Bangladesh from the four agricultural regions (Dhaka, Mymensingh, Sylhet, and Rangpur regions), where the intensity of local rice variety is more than the other regions. Out of these five districts, two are northwestern (Kurigram and Gaibanda representing the Rangpur region) and the other three are northeastern (Kishoregonj, representing Dhaka region; Netrokona, representing Mymensingh region; and Sunamgonj, representing Sylhet region) parts of Bangladesh (see the map in Figure 2). In the case of Aman season, popular local rice varieties *Biroi, Gainja,* and *Gainda* have been selected. We have selected the Netrokona purposively as the adoption intensity of *Biroi* is higher in the district. The adoption intensity of *Gainja* and *Gainda* is high in Kurigram and Gaibanda districts. In the case of Boro season, local *Rata boro* and *Tepi boro* have been selected to study. Therefore, Kishoreganj district has been selected purposively. Sunamgonj is popular for *Biroi, Rata boro*, and *Tepi boro* local rice varieties. To determine the sample size, we employed the following formula used by Rahman et al., (2022c) in a rice varietal adoption study in Bangladesh.

$$n = \frac{z^2 pq}{e^2} = \frac{(1.96)^2 * 0.5 * 0.5}{(0.05)^2} = 384.16 \cong 400 \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where n denotes the sample size, z^2 is the 95% confidence interval, p is the assessed share of an attribute of the population, $q=1-p$, and the anticipated precision level is e. First, a list of rice-growing farmers was collected from DAE for each of the selected blocks. From that list, 20 farmers from each block were selected randomly for interview. Forty rice-growing farmers from each Upazila have been interviewed face-to-face through a pre-structured and pre-tested questionnaire. The questionnaire was developed to gather information about the farm households' socio-economic status, modern rice cultivation, and local rice cultivation. Therefore, a total of 400 rice farmers were interviewed, with 80 from each of the selected districts.

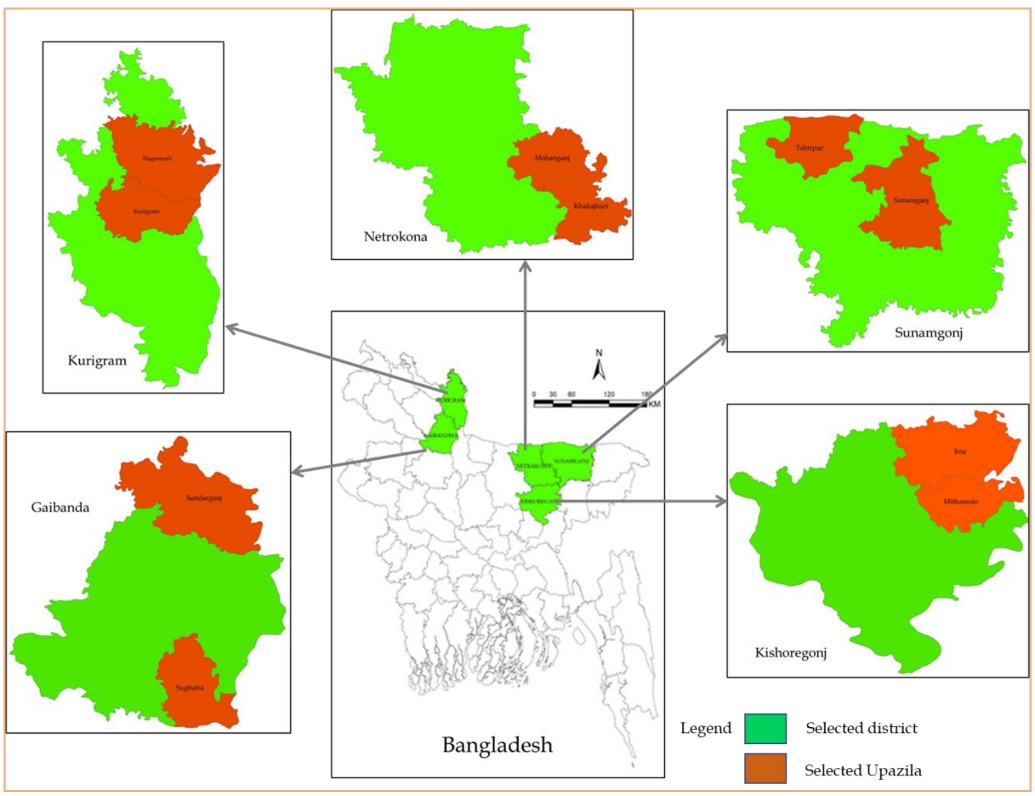


Figure 2. Study area

Analytical technique

Mainly, descriptive statistics, tabular techniques, activity budgeting, and fractional logistic regression have been employed in analyzing the collected data.

Profitability analysis

The profitability has been estimated through the following equation used by Rahman et al. (2015), Rahman and Rashid (2013), and Rahman (2012).

$$\mathbf{NR_i} = \sum_{i=1}^{n}\left(\mathbf{Y_i.P_{yi}} + \mathbf{Z_i.Q_i}\right) - \sum_{i=1}^{n}\left(\mathbf{X_i.P_{xi}}\right) - \mathbf{TFC_i} \qquad \text{.......................... (2)}$$

Where, NR_i = Net return or profit (BDT/ha) of the i^{th} farm; Y_i= Quantity of output (kg/ha) of the i^{th} farm; P_{yi}= Output price (BDT/kg) received by the i^{th} farm; Z_i= Quantity of byproduct (straw) (kg/ha) of i^{th} farm; Q_i= Price of byproduct (BDT/kg) by i^{th} farm; X_i= Quantity of inputs used (kg/ha) in rice farming by the i^{th} farm; P_{xi}= Price of inputs (BDT/kg) used in rice farming by the i^{th} farm; TFC_i= Total fixed cost (BDT/ha) of i^{th} farm; and i= Number of farms (1, 2, 3, …, n).

The fractional logistic regression model

Several empirical models have been used to analyze the intensity of adoption of agricultural technology, including poisson (Mahama et al., 2020; Kolady et al., 2021), Tobit (Murage et al., 2015; Gwada et al., 2019), fractional response (Papke and Wooldridge, 1996; Ansah and Tetteh, 2016; Pokhrel et al., 2018; Jelliffe et al., 2018; Misango et al., 2022). The model selection is subject to the nature of the dependent variable (Misango et al., 2022). Continuous variables are normally estimated through truncated regression, Tobit model, or censored model (Papke and Wooldridge, 1996; Gallani et al., 2015). These techniques do, however, have some limitations, particularly when the variable's dispersion is constrained on one or both sides, and a significant portion of the sample observations are located along one of the borders (Misango et al., 2022). The fractional response model or fractional logistic model is a workable solution for overcoming some of the economic constraints connected with the nonlinear techniques currently employed in modeling continuous bounded dependent variables (Papke and Wooldridge, 1996). We used a Fractional Logistic Regression (FLR) model developed to look at socioeconomic characteristics. It enables to capture of the non-linear connections, which is particularly useful when the proportion of adoption of local rice varieties is close to 0 or 1. When values fall into unit intervals, this regression model overcomes various difficulties more persuasively than other approaches using fractional response variables, such as Ordinary Least Square (OLS). Even though many authors employed binary econometric models to analyze technology adoption, log-odds regression might be imprecise because it involves indiscriminate adjustments for all parameters ranging from 0 to 1 (Chandio and Yuansheng, 2018; Muzari et al, 2012). Maximum Likelihood Estimation (MLE) on the other hand, estimates variables by maximizing a conditional probability and is known to be unreliable in the face of distributional collapse, as are nonlinear least squares. For overall efficiency, $Var(Y|X) = \sigma^2$ is required, which is implausible for proportional effectiveness (Gramig et al., 2008).

A quasi-MLE approach with a conditional mean criterion is known as fractional logistic regression. It provides a precise determination of the expected proportional dependent variables and the possibilities of a misspecified normal likelihood function (Greene 1951). The model developed by Papke and Wooldridge (1996) has the following form:

$$E(Y|X) = \frac{\exp(X\beta)}{[1 + \exp(X\beta)]} = \Lambda(X\beta) \qquad \text{............. (3)}$$

Where the anticipated coefficient of the independent variable X is denoted by $\beta's$. For observation i, the quasi-log likelihood is the same as for the logit binary response function:

$$l_i(\beta) = Y_i \log[\Lambda(X_i\beta)] + (1 - Y_i)\log[1 - \Lambda(X_i\beta)] \qquad \text{............ (4)}$$

Where $\Lambda(.)$ is the logistic Cumulative Distribution Function (CDF) and $Y_i \in [0, 1]$ which differs from the binary logit that limits $0 \leq Y \leq 1$. Although the estimates are dichotomous, they must be calculated using a completely robust variance predictor (Wooldridge 2010). The binary generalized linear model's variance condition necessitates a usually robust assumption, which is stated as:

$$Var(Y_i|X_i) = \sigma^2 p(X_i, \beta)[1 - p(X_i, \beta)] \qquad \text{........ (5)}$$

Where, $\sigma(X_i, \beta) = \Lambda\,(X_i\beta)$.

With a binomial dependent variable, the assessment of a linear regression necessitates the use of a binomial distributional and logit link function. However, the developed software by a statistical program did not include binary fractional response variables in this regard (Gramig et al., 2008).

The marginal effects of the independent variables can be derivative as follows,

$$X_k = \Pr(Y = 1|X, X_k = 1) - \Pr(Y = 1|X, X_k = 0) \qquad \text{..................(6)}$$

Model specification

The FLR model in this study is specified as follows:

$$E(Y|X_i) = \Lambda(\beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \cdots + \beta_{11} X_{11}) \qquad \text{................ (7)}$$

Where, Y is the adoption intensity of local rice varieties. X_1 = farmer's age (years); X_2 = education (years of schooling); X_3 = occupation dummy (1=only farming, 0=otherwise); X_4 = household size (no.); X_5 = annual family income; X_6 = farm size (decimal); X_7 = yield (ton/ha); X_8 = market rice (BDT/mound); X_9 = land type dummy (1=high/low, 0=favorable/normal); X_{10} = no. of varieties cultivated per farm; X_{11} = season dummy (1=Aman, 0=Boro), represents the socio-economic features of the selected rice farmers. The descriptive statistics of the considered variables of the FLR model have been presented in the appendix Table I. However, the diagnostic tests results also find that the residual of the estimated model is normally distributed (appendix Figure I) and the model is free from heteroscedasticity and multicollinearity problems (appendix Table II).

Results

Area Coverage of Selected Local Rice Varieties

Among the cultivated local rice varieties, *Biroi* is popular in the Mymensingh, Sylhet, and some parts (Kishoreganj and Tangail) of the Dhaka region. The variety covered 4866 hectares (ha) of land during 2020-21 with an average yield of 1.47 tons/ha. *Gainja* and *Gainda* are popular local rice varieties in the Rangpur region. *Gainja* is cultivated in the 44376 ha of land with an average yield of 1.54 tons/ha, whereas, *Gainda* covered 14571 ha of land with an average yield of 1.59 tons/ha. Very few local varieties are being cultivated in Boro season. The popular varieties are *Tepi boro* and *Rata boro*, cultivated mainly in Mymensingh, Sylhet, and Dhaka regions. *Tepi boro* has relatively wider coverage (1908 ha) than *Rata boro* (1083 ha). However, the yield of *Rata boro* (1.97 tons/ha) was better than that of *Tepi boro* (1.84 tons/ha) during 2020-21 (Table 2).

Table 2. Status of selected local rice varieties in Bangladesh during 2020-21

Season	Variety	Area coverage (ha)	Yield (ton/ha)	Production (ton)
Aman	*Biroi*	4866	1.47	7162.75
	Gainja	44376	1.54	66315.91
	Gainda	14571	1.59	20993.66
Boro	*Tepi boro*	1908	1.84	3517.53
	Rata boro	1083	1.97	2133.51

Note: Authors estimation is based on the data from DAE.

Comparative profitability of selected local and modern rice varieties cultivation

The local rice varieties required relatively fewer intercultural operations, herbicides, pesticides, and fertilizer. It would be worthy to mention that the local Aman varieties require zero irrigation as it is cultivated in the low-laying areas having water during the wet season (Table 3). The cost of pesticides was one-fourth of the modern varieties (MV) in the local Aman variety. Whereas in the Boro season, the cost of pesticides was almost double in the MVs compare to the local varieties. The cost of fertilizer was almost double in the MVs than the local rice varieties, irrespective of the seasons. The farmers are using less chemical fertilizers and pesticides for local rice cultivars, because of the soil fertility and ecology. The local rice growing areas are submerged and naturally remain more fertile than the normal plain land. Moreover, as the land contains water, using chemical fertilizers and pesticides would not be effective.

Table 3. Per hectare cost of local and MV rice cultivation in Bangladesh

Input-wise cost (BDT/ha)	Local Aman	MV Aman	Local Boro	MV Boro
Seedling development	2066	2350	2650	2750
Seed	1864	1824	2444	2099
Tillage	4845	6520	7995	7634
Human labor	39400	41589	49830	49930
Hired	12200	14338	14365	16425
Family	6630	6075	5450	6950
Hired contract (transplanting and harvesting)	20570	21176	30023	26555
Fertilizer cost	3301	8585	6500	13425
Irrigation	-	3450	13315	19350
Herbicide	352	460	349	730
Pesticides	1108	4440	2500	4373
Power thresher	3302	3080	4350	3990
Total variable cost	56238	72298	89933	104281
Interest on operating capital	1406	1807	2248	2607
Rental charges of own capital	20300	25600	19988	26000
Total fixed cost	21706	27407	22236	28607
Total cost	77944	99705	112169	132888

Note: Authors' calculations are based on data from a field survey. BDT= Bangladeshi Currency Taka.

The yield of the local rice varieties is much lower than that of the modern varieties. However, the market value of the local varieties for their grain quality compensated for the lower yield to make the cultivation profitable. The higher straw value of local rice varieties enhances the gross return of farmers (Table 4). The market price of the selected local Aman paddy varieties was 1.33 times that of modern varieties. Whereas, the market price of the selected local Boro varieties was 1.56 times that of modern varieties. According to the farmers, the straw from the local rice cultivars makes ideal cattle feed and fetches a higher price on the market. Therefore, the local varieties generated a better benefit-cost ratio (BCR) than the modern varieties in the respected areas.

Table 4. Per hectare profitability of local and MV rice cultivation in Bangladesh

Items	Local Aman	MV Aman	Local Boro	MV Boro
Total cost (BDT/ha)	77944	99705	112169	132888
Total variable cost (BDT/ha)	56238	72298	89933	104281
Total fixed cost (BDT/ha)	21706	27407	22236	28607
Yield (kg/ha)	2964	4841	3280	5730
Market value of paddy (BDT/ha)	88920	108923	123000	137520
Market value of straw (BDT/ha)	9000	8500	4675	5200
Gross return (BDT/ha)	97920	117423	127675	142720
Gross margin (BDT/ha)	41682	45125	37742	38439
Net return (BDT/ha)	19976	17718	15596	9832
Unit price of grain (BDT/kg)	30	22.5	37.5	24.00
Unit cost of production (BDT/kg)	26.30	20.60	34.20	23.19
BCR (cash cost basis)	1.74	1.62	1.42	1.37
BCR (full cost basis)	1.26	1.18	1.13	1.07

Note: Authors' calculations are based on data from a field survey.

Reasons for cultivating local rice varieties: an empirical approach

The adoption of local rice varieties among the sampled farm households in the research areas was influenced by socioeconomic parameters. Farmers' age, level of education, and farm size were all negatively linked with the adoption of local rice varieties, according to the findings of our quasi-MLE (Table 5). The older farmers are less likely to cultivate local rice varieties. This is because local rice cultivars are well-suited to the harsh conditions of the land, where older people hardly can work. Educated farmers were more likely to embrace modern rice varieties. Farmers having relatively large farm sizes are less likely to cultivate local rice varieties. According to the respondents, farmers who have more cultivable land were satisfied with the year-round family food security by producing HYVs in the standard plain farmland rather than cultivating in the very low or high lands (where only local rice varieties are suitable). Most of the cases, the larger farmers leased out the very high or low lands to the marginal or landless farmers.

Occupation, yield, market price, land type, and season are positively associated with the adoption of local rice varieties in the study areas. The farmers who are only involved in farming are more likely to cultivate local rice varieties besides the HYVs. They do not let any piece of land remain fallow. Because of the grain quality, the local rice varieties fetch a better market price. Hence, the farmers are likely to allocate land for local rice varieties alongside the HYVs. Low and high lands are less suitable for the HYVs to generate optimum yield. Therefore, farmers cultivate local rice varieties in the lower (in Aman season) and upper (in Boro season) lands as the local varieties are physiologically inherent to the respective adverse environmental conditions (Haque et al., 2022). In the adverse environmental condition, HYVs cannot provide satisfactory yield (Kamruzzaman et al., 2017), the exception are the varieties that developed targeting the stress ecosystems, whereas the local rice varieties can provide at least some yield to add to the farmers' food basket. The Boro season mostly depends on mechanical irrigation, whereas the Aman season mainly depends on rainfall irrigation. Aman season is more likely to be affected by excessive rainfall and flood. Therefore, farmers have to cultivate more local varieties in the Aman season than the Boro.

Other factors included in the model such as household size, household income, and the number of cultivated varieties do not significantly influence the adoption of local rice varieties in Bangladesh.

Table 5. Results Quasi-MLE of the fractional logistic regression for the adoption of local rice varieties

	Fractional logistic regression			Marginal effect		
	Coefficient	Robust S.E.	P-value	dy/ex	Delta-method S.E.	P-value
Farmer's age	-0.034***	0.012	0.005	-0.283***	0.092	0.002
Education	-0.079	0.053	0.140	-0.079	0.051	0.123
Occupation dummy	0.676**	0.316	0.041	0.182***	0.060	0.006
Household size	0.020	0.015	0.202	0.029***	0.013	0.042
Annual household income	0.001	0.003	0.813	0.019	0.080	0.814
Farm size	-0.001*	0.000	0.089	-0.043*	0.024	0.069
Yield	0.011***	0.002	0.001	0.012***	0.001	0.000
Price	0.019*	0.011	0.061	0.033**	0.013	0.039
Land type dummy	0.310***	0.025	0.000	0.511***	0.031	0.000
Number of variety	-0.077	0.280	0.785	-0.023	0.084	0.785
Season dummy	1.454*	0.785	0.064	0.153*	0.079	0.054
Constant	1.834	1.699	0.280			

Note: Superscripts '*', '**', and '***' represent significance at 10%, 5%, and 1% levels, respectively.

Discussion

Although more than 90% rice growing area is covered by modern rice varieties in Bangladesh, a significant portion (7.5%) is still under local cultivars. The local rice is produced with relatively low chemical fertilizer and pesticides than the MVs. Because of the grain quality, the market price of the local rice is much better than the MVs. Therefore, the local cultivars fetch more BCR than MVs. Abdul et al. (2016) and Alam et al. (2010) also got similar findings in the coastal and Haor regions of Bangladesh. Farmer's age is inversely correlated with the adoption intensity of local rice variety. This is because the young farmers are most likely to be risk lovers (Watson et al., 2017; Sarkar et al., 2022). The local varieties are being cultivated in relatively stress-prone areas, where farming is harder and riskier. The young farmers are more energetic and tend to take the risk of stress ecology to cultivate local rice varieties. Farm size is also negatively correlated with the adoption intensity of local rice varieties. That means, marginal and small farmers are likely to cultivate local rice cultivars. This is because marginal and small farmers want to maximize farm output by utilizing all the cultivable lands. They take the risk of cultivating local cultivars in the stress ecology to maximize output for household food security. A similar finding is presented by Ricciardi et al. (2018) that the small farmers like to cultivate diversified crops for maximizing farm output. The land type in this study represents the stressful environment. A very low or high land is an adverse condition for rice cultivation where HYVs can not sustain. The local rice cultivars are popular in the flood, haor, drought, tidal, and hill ecosystems of Bangladesh. The local cultivars are mostly cultivated to address the impact of the climate hazard as an adaptation option (Kamruzzaman et al., 2017; Keleman Saxena et al., 2016). Yield and market price are the most important factors that determine the adoption intensity of any variety (Sarkar et al., 2022; Pratt et al., 2021; Rahaman et al., 2020) as these factors influence the profit for farmers (Michler et al., 2019). Farmers, in some cases, in the study areas, wish to cultivate more of the local rice cultivars because of their better market price and unique attributes. In the respective stress ecosystems, local rice cultivars perform well and provide some yield where HYV's yield is almost zero. Farmers also informed that better market price and eating quality compensated for the lower yield of local rice cultivars and achieved popularity in the respective cultivated areas. As a result, while the yield of local rice varieties is relatively low, in comparison to the stressful ecology, their performance is praised as helping the nation strengthen food security.

Conclusion and Policy Recommendation

This study was designed to figure out the causes of cultivating local rice varieties in Bangladesh by implementing cognitive and empirical approaches. The findings of the study reveal that farmers cultivate local rice varieties because of the existence grain quality and ecological attributes that are absent in HYVs and Hybrids. The primary quality of local rice cultivars that continues to entice farmers to set aside areas for cultivation is their potential for adaptation in stressed ecosystems. The unique grain quality of local rice cultivars fetches higher demand and market prices that compensate for their lower yield. The farmers get relatively more profit by cultivating local rice cultivars. Moreover, growing local rice varieties can help increase the availability of feed for livestock. The socio-economic characteristics of the farm households such as the farmer's age, occupation, and farm size have a significant influence on adopting local rice cultivars. Yield, market price, and land topography are the agronomic and market factors that have a strong influence on cultivating local rice cultivars in Bangladesh. However, the yield of local rice cultivars is much lower than the HYVs and hybrids. But, the HYVs and hybrids are not suited as much as the local rice cultivars in the stress-prone areas. Therefore, plant breeders should consider the attributes of local rice cultivars to genetically develop modern rice varieties suitable for cultivation in stress ecosystems. The scientists also should develop suitable cultivation packages (such as planting and harvesting time, cropping pattern, agronomic management, water management, etc.) in the local rice varieties intensive areas for better management to boost rice yield.

References

Abdul, H., Jafar, U., Altaf, H., Aminul, I. and Shahrina, A. 2016. Response of indigenous rice cultivars to applied fertilizers in tidal floodplain of south central coastal region of Bangladesh. *Academia Journal of Agricultural Research,* 4(4): 168-175.

Alam, M.S., Quayum, M.A. and Islam, M.A. 2010. Crop production in the Haor areas of Bangladesh: insights from farm level survey. *The Agriculturists*, 8(2): 88-97.

Ansah, I.G.K. and Tetteh, B.K. 2016. Determinants of yam postharvest management in the Zabzugu District of Northern Ghana. *Advances in Agriculture*, 2016: 1-9. http://dx.doi.org/10.1155/2016/9274017

Aziz, M., Shohan, H.U.S., Rahman, N.M., Rahman, M.C., Nihad, S.A.I., Hassan, S.M., Kabir, M., Hossain, M., Ahmed, R., Qayum, M. and Mamun, M. 2022. Projection of Future Precipitation in Bangladesh at Kharif-II Season Using Geospatial Techniques. *Earth Systems and Environment*, 7(1): 255-266.

Chandio, A.A. and Yuansheng, J.I.A.N.G. 2018. Determinants of adoption of improved rice varieties in northern Sindh, Pakistan. *Rice Science* 25(2): 103-110.

Gallani, S., Krishnan, R. and Wooldridge, J.M. 2015. *Applications of fractional response model to the study of bounded dependent variables in accounting research*. Harvard Business School.

Gramig, B.M., Wolf, C.A. and Lupi, F. 2008. Fractional Logit Estimation Method for Economic Analysis of Herd-level Livestock Health: Bovine Leukosis Virus on U.S. Dairy Farms. *Poster presented in the Michigan State University*. https://msu.edu/~lupi/FractionalLogit_Adoption-isk_models.pdf. Accessed 30 May 2022.

Greene, W.H. 1951. *Econometric Analysis*. 7th edition Upple Saddle River, NJ: Prentice Hall.

Gwada, O.R., Bett, K.H. and Sibiko, W.K. 2019. Factors influencing the extent of Push-pull technology expansion among smallholder maize farmers in Homa Bay, Kenya. *J. Econ. Sustain. Dev*, 10(7): 72-84.

Haque, A.E., Mukhopadhyay, P., Nepal, M. and Shammin, M.R. 2022. South Asian stories of climate resilience. *Climate Change and Community Resilience,* 1. Springer Nature, Singapore. https://doi.org/10.1007/978-981-16-0680-9

Islam, M.A., Rahman, M.C., Sarkar, M.A.R. and Siddique, M.A.B. 2019. Assessing impact of BRRI released modern rice varieties adoption on Farmers' welfare in Bangladesh: application of panel treatment effect model. *Bangladesh Rice Journal,* 23(1): 1-11.

Islam, M.Z., Khalequzzaman, M., Bashar, M.K., Ivy, N.A., Haque, M.M., Mian, M.A.K. and Tomita, M. 2018. Agro-morphological Characterization of Bangladeshi Aromatic Rice (*Oryza sativa* L.) Germplasm Based on Qualitative Traits. *Bangladesh Rice Journal,* 22(2): 41-54.

Jelliffe, J.L., Bravo-Ureta, B.E., Deom, C.M. and Okello, D.K. 2018. Adoption of high-yielding groundnut varieties: The sustainability of a farmer-led multiplication-dissemination program in Eastern Uganda. *Sustainability*, 10(5): 1597.

John, D.A. and Babu, G.R. 2021. Lessons from the aftermaths of green revolution on food system and health. *Frontiers in sustainable food systems*, 5: 644559.

Kabir, M.J., Sarkar, M.A.R., Rahman, M.C., Rahman, N.M.F., Mamun, M.A.A., Chowdhury, A., Salam, M.U. and Kabir, M.S. 2021. Risk of rice cultivation under current and future environment and market. *Bangladesh Rice Journal,* 25(1): 101-110.

Kabir, M.S., Salam, M.U., Islam, A.K.M.S., Sarkar, M.A.R., Mamun, M.A.A., Rahman, M.C., Nessa, B., Kabir, M.J., Shozib, H.B., Hossain, M.B. and Chowdhury, A. 2020. Doubling rice productivity in Bangladesh: A way to achieving SDG 2 and moving forward. *Bangladesh Rice Journal,* 24(2): 1-47.

Kamruzzaman, M.D., Al Marjuk, O. and Alam, M. 2017. Local rice varieties in climate vulnerable areas of Bangladesh: prospects and barriers. *Proceedings of 7th International Symposium, SEUSL, Sri Lanka*.

Keleman Saxena, A., Cadima Fuentes, X., Gonzales Herbas, R. and Humphries, D.L. 2016. Indigenous food systems and climate change: impacts of climatic shifts on the production and processing of native and traditional crops in the Bolivian Andes. *Frontiers in public health,* 4: 20.

Kolady, D.E., Van der Sluis, E., Uddin, M.M. and Deutz, A.P. 2021. Determinants of adoption and adoption intensity of precision agriculture technologies: evidence from South Dakota. *Precision Agriculture*, 22(3): 689-710.

Mahama, A., Awuni, J.A., Mabe, F.N. and Azumah, S.B. 2020. Modelling adoption intensity of improved soybean production technologies in Ghana-a Generalized Poisson approach. *Heliyon*, 6(3): e03543.

Mainuddin, M., Karim, F., Gaydon, D.S. and Kirby, J.M. 2021. Impact of climate change and management strategies on water and salt balance of the polders and islands in the Ganges delta. *Scientific Reports*, 11(1): 1-15.

Michler, J.D., Tjernström, E., Verkaart, S. and Mausch, K. 2019. Money matters: The role of yields and profits in agricultural technology adoption. *American Journal of Agricultural Economics,* 101(3): 710-731.

Misango, V.G., Nzuma, J.M., Irungu, P. and Kassie, M. 2022. Intensity of adoption of integrated pest management practices in Rwanda: A fractional logit approach. *Heliyon*, 8(1): e08735.

Mottaleb, K.A., Mohanty, S. and Nelson, A. 2015. Factors influencing hybrid rice adoption: a Bangladesh case. *Australian Journal of Agricultural and Resource Economics*, 59(2): 258-274.

Murage, A.W., Midega, C.A.O., Pittchar, J.O., Pickett, J.A. and Khan, Z.R. 2015. Determinants of adoption of climate-smart push-pull technology for enhanced food security through integrated pest management in eastern Africa. *Food Security,* 7(3): 709-724.

Muzari, W., Gatsi, W. and Muvhunzi, S. 2012. The impacts of technology adoption on smallholder agricultural productivity in sub-Saharan Africa: A review. *Journal of Sustainable Development,* 5(8): 69.

Papke, L.E. and Wooldridge, J.M. 1996. Econometric Methods for Fractional Response Variables with an Application to 401 (k) Plan Participation Rates. *Journal of Applied Econometrics,* 11(6): 619-632.

Pokhrel, B.K., Paudel, K.P. and Segarra, E. 2018. Factors affecting the choice, intensity, and allocation of irrigation technologies by US cotton farmers. *Water*, 10(6): 706.

Pratt, B., Tanner, S. and Thornsbury, S. 2021. Behavioral Factors in the Adoption and Diffusion of USDA Innovations. *US Department of Agriculture*.

Rahaman, M.S., Sarkar, M.A.R., Rahman, M.C. and Kabir, M.J. 2020. Drivers of adoption of BRRI cultivars in Boro season among farm households of Mymensingh district, Bangladesh. *Journal of the Bangladesh Agricultural University,* 18(3): 660-666.

Rahaman, M.S., Sarkar, M.A.R., Rahman, M.C., Limon, D.E.B., Rashid, M.M., Reza, M.S. and Siddique, M.A.B. 2022. Profitability analysis of paddy production in different seasons in Bangladesh: Insights from the Haor. *International Journal of Agriculture Environment and Food Sciences*, 6(3): 327-339.

Rahman, M.C. 2012. Economic Study on Paddy and Golda Farming in Polder 31 at Dacope Upazila of Khulna District. Mater of Science dissertation, Bangladesh Agricultural University, Mymensingh, Bangladesh. https://doi.org/10.13140/RG.2.2.21188.58247

Rahman, M.C., Islam, M.A., Rahaman, M.S., Sarkar, M.A.R., Ahmed, R. and Kabir, M.S. 2021a. Identifying the threshold level of flooding for rice production in Bangladesh: An Empirical Analysis. *Journal of the Bangladesh Agricultural University,* 19(2): 243-250.

Rahman, M.C., Miah, T.H. and Rashid, M.H. 2015. Effects of controlling saline water intrusion in an empoldered area of Bangladesh. In *Revitalizing the Ganges Coastal Zone: Turning Science into Policy and Practices Conference Proceedings. Colombo, Sri Lanka: CGIAR Challenge Program on Water and Food (CPWF),* 89.

Rahman, M.C., Pede, V., Balie, J., Pabuayon, I.M., Yorobe, J.M. and Mohanty, S. 2020. Assessing the market power of millers and wholesalers in the Bangladesh rice sector. *Journal of Agribusiness in Developing and Emerging Economies,* 11(3): 280-295.

Rahman, M.C., Pede, V.O. and Balié, J. 2022b. Welfare impact of asymmetric price transmission on rice consumers in Bangladesh. *Review of Development Economics,* 26(3): 1600-1617. https://doi.org/10.1111/rode.12882

Rahman, M.C., Rahaman, M.S., Biswas, J.C., Rahman, N.M., Islam, M.A., Sarkar, M.A.R., Islam, M.S. and Maniruzzaman, M. 2022a. Climate change and risk scenario in Bangladesh. *Asia-Pacific Journal of Regional Science*, 1-24. https://doi.org/10.1007/s41685-022-00252-9

Rahman, M.C., Rashid, M.H.A. 2013. A case study on the present status and potentiality of shrimp farming in Bangladesh. *Asia-Pacific Journal of Rural Development,* 23(1): 97-110.

Rahman, M.M., Biswas, J.C., Sutton, M.A., Drewer, J. and Adhya, T.K. 2021b. Assessment of reactive nitrogen flows in Bangladesh's agriculture sector. *Sustainability*, 14(1): 272.

Rahman, M.S., Sujan, M.H.K., Acharjee, D.C., Rasha, R.K. and Rahman, M. 2022c. Intensity of adoption and welfare impacts of drought-tolerant rice varieties cultivation in Bangladesh. *Heliyon*, e09490.

Rahman, N.M.F., Malik, W.A., Kabir, M.S., Baten, M.A., Hossain, M.I., Paul, D.N.R., ... and Piepho, H.P. 2023. 50 years of rice breeding in Bangladesh: genetic yield trends. *Theoretical and Applied Genetics*, 136(1): 1-13.

Ricciardi, V., Ramankutty, N., Mehrabi, Z., Jarvis, L. and Chookolingo, B. 2018. How much of the world's food do smallholders produce?. *Global food security,* 17: 64-72.

Sarkar, M.A.R., Rahman, M.C., Rahaman, M.S., Sarker, M.R., Islam, M.A., Balie, J. and Kabir, M.S. 2022. Adoption Determinants of Exotic Rice Cultivars in Bangladesh. *Frontiers in Sustainable Food Systems,* 6: 813933.

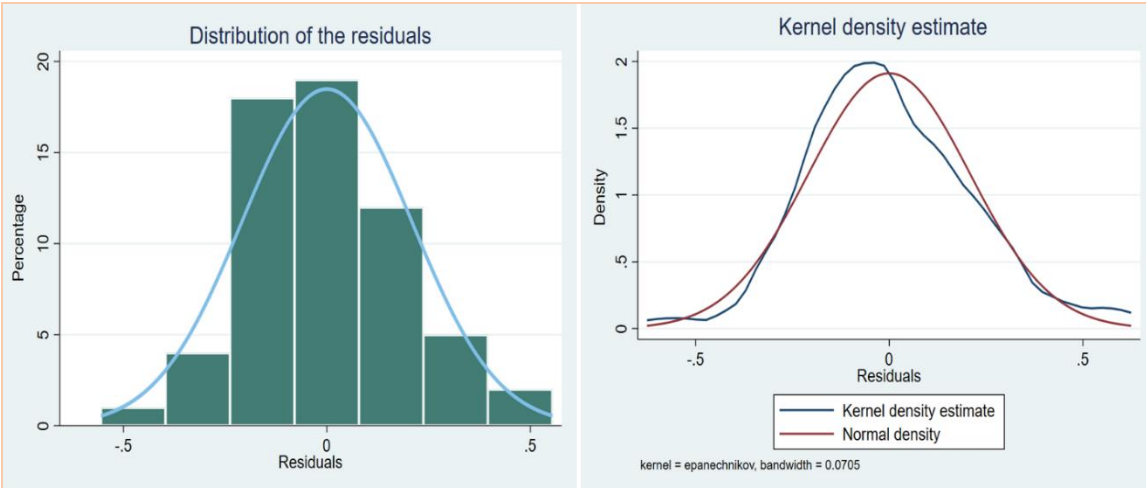
Shelley, I.J., Takahashi-Nosaka, M., Kano-Nakata, M., Haque, M.S. and Inukai, Y. 2016. Rice cultivation in Bangladesh: present scenario, problems, and prospects. *Journal of International Cooperation for Agricultural Development,* 14: 20-29.

Watson, D., Kenny, O., Maitre, B. and Russell, H. 2017. *Risk Taking and Accidents on Irish Farms: An Analysis of the 2013 Health and Safety Authority Survey*. Esri research series number 60, May 2017.

Wooldridge, J.M. 2010. *Econometric Analysis of Cross Section and Panel Data*. 2nd edition Cambridge, MA: MIT Press.

Yeasmin, H., Sanawar, S.B., Sharmin, S. and Islam, M.A. 2020. Efficient use of agricultural land in Bangladesh: Strategies for optimization. *Bangladesh Journal of Agricultural Economics*, 41(454-2020-1360): 35-45.

APPENDICES



Appendix Figure I. Test for normality of the residuals

Appendix Table I: Description of the variables included in the Fractional Logistic Regression and Tobit Regression models (n=400).

Variable	Description	Mean	CV	Maximum	Minimum
Adoption intensity of local rice variety	Ratio of areas covered by the local varieties over total rice area by the individual sampled farmers. The value ranges between 0 and 1	0.45	0.719	1.00	0.03
Farmer's age	Years	44.89	0.352	80.00	17.00
Education	Years of schooling	5.26	0.731	13.00	0.00
Occupation dummy	1, if only agriculture; 0, otherwise	0.84	0.446	1.00	0.00
Household size	Number of family members	5.93	0.246	9.00	3.00
Annual household income	Thousand BDT	126.49	0.408	250.00	70.00
Farm size	Cultivable land in decimal	396.15	1.341	4000.00	100.00
Yield	Amount of rice produced (tons per hectare)	3081.14	0.226	4347.20	1646.67
Price	Market value of paddy BDT per mound	1243.28	0.278	2000.00	700.00
Land type dummy	1, if high/low; 0, if favorable/normal	0.93	0.231	1.00	0.00
Number of varieties	Number of cultivated rice varieties per farm	1.57	0.375	3.00	1.00
Season dummy	1, if Aman; 0, if Boro	0.51	0.992	1.00	0.00

Note: CV= Coefficient of variation

Appendix Table II: Residual diagnostic tests

Test for Multicollinearity	
Variable	**Variance Inflation Factor (VIF)**
Season dummy	6.21
Price	3.99
Annual income	1.9
Number of varieties	1.4
Land type dummy	1.39
Farmer's age	1.38
Education	1.35
Yield	1.21
Occupation dummy	1.14
Household size	1.12
Farm size	1.06
Mean VIF	2.08
Test for Heteroscedasticity	
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity Ho: Constant variance Variables: fitted values of Adoption intensity of local rice variety Chi-square ($chi - squared$) value = 2.01 Probability value of Chi-square ($chi - squared$) = 0.1559	