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FACTORS DRIVING THE SHIFTING OF LAND FROM RICE TO AQUACULTURE FARMING IN BANGLADESH

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Abstract. Farmers' decisions regarding land usage have evolved over time. Small farmers have a tendency to make a variety of land usage choices. This study examined the relative profitability and determining factors of shifting cultivation. A total of 110 farmers were selected using a multistage random sampling technique. The objectives of the study were attained using descriptive statistics and Probit regression. The results indicated that the decision to shift land towards small-scale aquaculture is financially profitable. The econometric model indicated that occupation, education, farm size, and perception of rice price had a significant impact on the decision to shift land. Farmers who perceive a lower rice price are 6.1% more likely to shift than those who perceive a higher price. Capital shortage and a high cost of feed in shifting cultivation were among the various obstacles respondents faced. If a rice farm undergoes conversion into a fish farm, it is imperative for the government to enact policies that can facilitate farmers in making informed decisions.

Keywords: aquaculture, income, probit model, rice, shifting cultivation

INTRODUCTION

Agriculture contributes approximately 12% to Bangladesh's Gross Domestic Product (GDP), with the sub-sectors of crops and horticulture witnessing a growth rate of approximately 1% in fiscal year 2021–22, compared to the fiscal year 2020–21 (BBS, 2022). Nearly 15 million farm families in Bangladesh grow rice on 14.9 million ha of land, or 78% of cultivable land (Gurung et al., 2016), making rice cultivation the primary economic activity in the country. Rice makes up nearly two-thirds of the daily diet, with some fish eaten occasionally. Broadcast aman rice (summer season rice) production was the primary user of low-lying paddy fields until the 1960s (Akteruzzaman, 2005). Farmers began growing boro rice during the Rabi (winter) season after being exposed to modern rice farming techniques. Over the past few decades, however, Bangladesh has shifted away from its traditional paddy-based farming systems in favor of aquaculture (Ahmed et al., 2011; Dey et al., 2013; Sattar, 2019). Farmers have begun using their paddy fields for alternate rice-fish farming and rice-cum fish farming as a result of advances in aquaculture technology and the realization that fish farming is more profitable than rice cultivation. Farmers in low-lying inland areas were motivated to introduce a fish-based cropping system due to the high net income generated by such a system in the 1980s to the mid-1990s, when some rice fields were converted into fishponds and people began producing fish for commercial purposes (Akteruzzaman, 2005).

However, a number of technical barriers prevent the widespread adoption of integrated rice-fish farming technologies. It takes more time and money to manage water for a rice-fish field than it would for a rice-only

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field. If fish farming is done at the same time as rice production, introduced carps could potentially wipe out the rice crop (Khandoker et al., 2017). The irrigated lands of Bangladesh can produce three crops per year. The costs and benefits of implementing the change for integrated rice-fish farming in one season will be felt in subsequent seasons. Since aquaculture is more lucrative than rice farming and integrated rice-fish farming has some limitations, farmers have recently begun transforming their lands into permanent ponds for small-scale aquaculture. A lot of rice fields have been converted into freshwater ponds for fish to meet the domestic demand for protein and to significantly increase farm income (Akteruzzaman, 2005; Sattar, 2019).

Land use decisions made by farmers in Bangladesh have evolved over time. Different types of land use decisions are more common among small farmers (Islam et al., 2020). The transition from rice farming to aquaculture is a subject of ongoing deliberation within the agricultural land usage policy of Bangladesh, which has the potential to impact the farmers' capacity to enhance the array of their income sources (Rahman et al., 2022). Farmers' perceptions of profitability, amount of land owned, level of education, annual income, and farming experience are all important considerations when making the switch from rice cultivation to small-scale aquaculture (Anisuzzaman et al., 2015; Rasel, 2016). Few studies have been done in the context of Bangladesh to determine what causes farmers to shift their land – particularly on integrated rice-fish farming (Ahmed and Garnett, 2011; Islam et al., 2015). A few studies have measured the financial profitability of aquaculture farmers in Bangladesh (Hossain et al., 2022; Mitra et al., 2022). Nevertheless, there is a scarcity of research regarding the comparative profitability of farmers who switched from rice farming to pond-based small-scale aquaculture, as well as the underlying factors that drive this decision. This study shed light on the realities facing rural areas that have converted rice land to small-scale pond-based aquaculture. The results may provide policymakers in Bangladesh with useful information as they consider how to best support the growth of rice production and small-scale aquaculture. With this context in mind, we set out to determine the relative financial profitability of rice and fish farming and to identify the factors that influence farmers to make the switch from rice to small-scale aquaculture.

MATERIAL AND METHOD

Data sources

The study's sample was selected using a multistage random sampling technique. At first, Cumilla district (administrative unit) was selected purposively due to availability of farmers who shifted their land towards small-scale aquaculture. When it comes to the cultivation of fish in 2018 in Bangladesh, the Cumilla district ranked third overall (BBS, 2018). The second step involved selecting the upazilas (subdistricts), Chauddagram and Nangolkot, for an in-person interview. The farmers' availability was taken into account when choosing the final two villages from each upazila. Each village's list of people was compiled with the aid of the extension service. 540 households were counted across four villages. Finally, 20% of the total households were selected randomly as a sample in accordance with the methods described by Kabir et al. (2022) and Sam et al. (2020). Thus, 110 farmers were surveyed in total. Sixty farmers out of 110 shifted their land from rice to fish cultivation, while the remaining farmers did not shift their land. Two out of 60 shifted farmers were unable to provide information on the cost and return of fish cultivation. Consequently, they were excluded from analysis. Eight of the 50 non-shifted farmers suffered significant losses from rice cultivation in 2018 and did not provide cost and return information on rice farming. These 8 farmers who had not shifted were also excluded from the analysis. In the end, 100 farmers, including 42 rice farmers (non-shifted farmers) and 58 aquaculture farmers (shifted farmers), were considered for the analysis. The background information, expert's evaluation, and pre-test questionnaire were used to develop a structured interview schedule.

Analytical techniques

Profitability analysis

Before calculating the relative profitability of shifting cultivation, the costs and returns of the entire annual cropping pattern for non-shifted farmers were estimated. Finally, the overall cropping pattern's profit was compared to the profit of fish farming. The per-hectare cost of variable inputs such as land preparation, labor, seed, fertilizer, irrigation, and insecticides were determined. The cost of land use was calculated using the land's annual lease value. The gross margin was determined by subtracting the gross return from the total variable costs.

To estimate net income, total costs were deducted from total revenue. The total cost comprises both variable and fixed costs. Using the following formula (equation 1), interest on operating capital was calculated:

$$\text{Interest on operating capital} = AI \cdot i \cdot t \qquad (1)$$

where:
- AI – average investment;
- t – total time period of investment;
- i – interest rate, which was assumed to be 10% per year.

A benefit-cost ratio (BCR) is an indicator that illustrates the monetary relationship between the relative costs and benefits of an investment. If the BCR of an investment is greater than 1, it is anticipated that it will generate a positive net present value for a farm. The following formula (equation 2) was used to calculate the BCR:

$$\text{BCR} = \frac{\text{GR}}{\text{TC}} \qquad (2)$$

where:
- GR – gross return,
- TC – total cost.

Factors affecting land shifting

The random utility theory served as a framework for the analysis of land shifting decisions in this study. Given the socio-economic and technological characteristics, it was assumed that the utility gain from aquaculture would be greater than that of traditional crop cultivation, and that farmers would choose to adopt and continue the new practice if the utility gain is greater than that of the older technology. The study used a binary Probit model to determine the factors that influence land-shifting decisions. The farmers who don't shift their land towards aquaculture may be unwilling to do so because of their socioeconomic constraints. Therefore, several socio-economic characteristics-related independent variables were used in the model (Table 1). The likelihood of shifting cultivation can be written as follows (equation 3):

Table 1. Description of the variables used in the model

Variable	Description	Average/percent value	
		non-shifted farmers	shifted farmers
1	2	3	4
Personal characteristics			
Age (x_1)	Farmers age in years	48	44
Primary education (x_2)	A dummy variable that takes a value of 1 if the farmer has primary level of education, 0 otherwise	0.33	0.12
Secondary education (x_3)	A dummy variable that takes a value of 1 if the farmer has secondary or higher education, 0 otherwise	0.31	0.47
Spouse education (x_4)	Years of schooling of primary farmer's spouse	5.67	8.83
Occupation (x_5)	A dummy variable that takes a value of 1 if the farmer's main occupation is agriculture, 0 otherwise	0.76	0.95
Economic characteristics			
Earning member (x_6)	Number of earning member in the family	1.16	1.57
Farm size (x_7)	Total farm size in hectare	1.09	5.62
Institutional characteristics			
Training (x_8)	A dummy variable that takes a value of 1 if the farmer has training in fish cultivation, 0 otherwise	0.22	0.45

Table 1 – cont.

1	2	3	4
Societal membership (x_9)	A dummy variable that takes a value of 1 if the farmer has any societal membership, 0 otherwise	0.35	0.41
Contact with SAAO (x_{10})	A dummy variable that takes a value of 1 if the farmer has contact with local extension personnel (SAAO), 0 otherwise	0.26	0.40
Distance from DAE office (x_{11})	Distance of agricultural extension office (DAE) office from farmers house in km	5.10	5.08
Perception price of rice (x_{12})	A dummy variable that takes a value of 1 if the farmer perceived lower price of rice, 0 otherwise	0.75	0.95
Access to credit (x_{13})	A dummy variable that takes a value of 1 if the farmer has received credit from formal source (bank), 0 otherwise	0.30	0.51

Average is calculated for continuous variables. Percentage is used for dummy variables. Source: own elaboration.

$$\text{Prob (land shifted towards aquaculture = 1)} = \frac{\exp(\beta V_i)}{1+\exp(\beta V)} \quad (3)$$

where:

Prob – represents probability,

V_i – are independent variables,

β – represents parameters to be estimated.

The likelihood of non-shifting can be written as follows (equation 4):

$$\text{Prob (non – shifting 0)} = \frac{1}{1+\exp(\beta V_i)} \quad (4)$$

The following empirical Probit model (equation 5) was used (Ashfaq et al., 2008):

$$Y_s^* = Y_s - Y_{ns} > 0 = \beta_o + \beta_1 \text{ age} + \beta_2 \text{ primary education} + \beta_3 \text{ secondary education} + \beta_4 \text{ spouse education} + \beta_5 \text{ earning member} + \beta_6 \text{ occupation} + \beta_7 \text{ training} + \beta_8 \text{ societal membership} + \beta_9 \text{ contact with SAAO} + \beta_{10} \text{ farm size} + \beta_{11} \text{ distance from DAE office} + \beta_{12} \text{ rice price perception} + \beta_{13} \text{ credit access} + u_i \quad (5)$$

where:

Y_i^* – is the latent variable representing the probability of farmers deciding to shift their land,

u_i – error term and $u_i \sim N(0, 1)$,

Y_s and Y_{ns} represents shifted and not-shifted farmers, respectively. Marginal effect was also estimated to interpret the results.

Ethical consideration

The Review Committee of the Department of Agricultural Economics, Sher-e-Bangla Agricultural University, Bangladesh, granted ethical approval. Each respondent provided verbal informed consent after being informed of the study's objectives, its significance, and the variety of information required. Participation in the study by respondents was voluntary. Respondents were free to refuse or discontinue the interview at any time. If a respondent refused to be interviewed, another household was contacted.

RESULTS

Cost structure of shifted and non-shifted farmers

According to the findings, total production costs for fish farming are much higher than those for rice farming (Table 2). The annual costs for a farmer engaged in three seasons of rice cultivation were determined to be Tk. 232157 (USD 2211), whereas the annual costs for a fish farming farmer were estimated to be Tk. 1206185 (USD 11488). The largest portion of the total cost comes from variable cost items. In fish farming, variable costs account for roughly 80% of total costs, while in rice farming, they account for roughly 64%. In fish farming, the costliest components are fish feed and fingerlings, whereas in rice farming, labor constitutes the most substantial expenditure, followed by fertilizer costs.

Table 2. Annual per hectare cost of production

Cost items	Shifted farmers	Non-shifted farmers
Variable cost		
Labor cost	92 449	62 000
Tillage cost /pond preparation	36 444	18 462
Seed /fingerling cost	98 619	12 418
Feed cost	542 000	–
Fertilizer cost	2 760	26 798
Weeding	–	7 134
Irrigation	28 047	16 070
Pesticides/ medicine	85 871	1 684
Salt/lime	8 688	
Interest on operating capital	57 437	3 805
Total variable cost	952 315	148 371
Fixed cost		
Land use cost	233 693	83 785
Fishing net /fencing	20 177	–
Total fixed cost	253 870	83 785
Total cost (A+B)	1 206 185	232 157

Tk is Bangladeshi currency. 1 USD = Tk 105.
Source: own elaboration based on field survey, 2019.

Comparative financial profitability

The annual per hectare cost and profit of farming crops and aquaculture are detailed in Table 3. The total annual production cost and return of shifted farmers (fish farming) per hectare is significantly higher than that of non-shifted farming (rice farming). Benefit cost ratio (BCR) of 1.57 shows that fish farming is more profitable than rice farming despite requiring a higher initial investment. When considering all production costs, including the valuation of rented land, rice farming is found to be not profitable.

Table 3. Relative profitability of shifted and non-shifted farmers

Items	Shifted farmers (Tk.)	Non-shifted farmers (Tk.)
Gross return	1 897 325	216 531
Total variable cost	952 315	148 371
Total cost	1 206 185	232 157
Gross margin	945 010	68 160
Net return	691 140	–15 626
Undiscounted BCR	1.57	0.93

Tk is Bangladeshi currency. 1 USD = Tk 105.
Source: own elaboration based on field survey, 2019.

Factors affecting shifting of land

The results of Probit regression model analysis are presented in Table 4. The significant LR chi-squared value and the Pseudo R^2 indicate a good fit of the model. The variance inflation factor (VIF) was used to assess multicollinearity among the explanatory variables. The VIF for all variables (ranging from 1.22 to 3.49) was found to be below 10, suggesting that the issue of multicollinearity does not pose a significant concern in the estimation of the model in this study. Therefore, the model included all the proposed explanatory variables. Farmers' decisions to switch from rice to fish cultivation were significantly influenced by 5 of the 13 explanatory variables (occupation, training, farm size, perception, and access to formal credit).

The marginal effects suggested that the likelihood of shifting is 3.6% higher for farmers whose main occupation is agriculture compared to those whose main occupations are not in agriculture. The probability of shifting is 4.8% higher for farmers who received training in fish cultivation compared to those who did not receive any training in fish farming. The findings further suggested that, keeping other things constant, if farm size is increased by 1 hectare, then the possibility of shifting land towards aquaculture is increased by 3.5%. The likelihood of shifting is 6.1% higher for farmers who perceived a lower price of rice compared to others. Farmers who have access to formal credit are 5.7% more likely to change their land use than those who do not.

Contribution of fish income

According to the results, shifted farmers were better off financially than their non-shifted counterparts. Table 5 shows that rice farming contributed 22.29% to the total income of rice farmers, while fish farming contributed 91.82% to the total income of farm households.

The constraints of shifting cultivation

There is no doubt that fish farming is a lucrative endeavor, but the farmers encountered numerous obstacles when shifting their operations. In fish cultivation, a high

Table 4. Estimated co-efficient and marginal effect after Probit regression

Explanatory Variable	Coefficient	Standard error	z statistic	Marginal effect
Intercept	–3.36	1.58	–2.13	—
Age (x_1)	–0.01	0.01	–0.84	–0.003
Primary education (x_2)	0.80	0.77	1.03	0.16
Secondary education (x_3)	0.92	0.69	1.33	0.26
Spouse education (x_4)	0.06	0.06	1.09	0.02
Earning member (x_5)	0.08	0.21	0.39	0.02
Occupation (x_6)	0.97**	0.46	2.10	0.29*
Training (x_7)	1.01**	0.51	1.98	0.22**
Societal membership (x_8)	–0.05	0.57	–0.09	–0.01
Contact with SAAO (x_9)	0.09	0.58	0.16	0.02
Farm size (x_{10})	0.83**	0.39	2.10	0.21***
Distance to DAE office (x_{11})	–0.02	0.13	–0.17	–0.006
Perception price of rice (x_{12})	2.26***	0.47	4.76	0.61***
Access to formal credit (x_{13})	0.22*	0.12	1.85	0.057*
LR chi-squared	79.35***			
Pseudo R^2	0.58			

*, ** and ** indicate significant at 10%, 5%, and 1% level, respectively.
Source: own elaboration based on field survey, 2019.

Table 5. Contribution of farm income on total income

Income source	Non-shifted farmers (Tk.)	Shifted farmers (Tk.)
Agriculture	100 547	3 830 515
Non-agricultural income	232 212	269 672
Total income	332 760	4 100 187
Rice / fish farming income	74 188 (22.29)	3 764 956 (91.82)

Figures in the parentheses indicate percentage of total income; Tk is Bangladeshi currency.
1 USD = Tk 105.
Source: own elaboration based on field survey, 2019.

Table 6. Constraints faced by shifted farmers

Problems	Percentage of farmers
Lack of capital	74
High feed price	74
Disease proneness of fish	16
Lack of market information	5
Lack of technical know-how	5

Source: own elaboration based on field survey, 2019.

proportion (74%) of respondents experienced severe capital shortage and high feed prices, as shown in Table 6. Disease susceptibility of fish may also pose threats to fish farmers. To overcome the constraints, farmers also proposed a few measures, including a reduction in feed prices, the provision of subsidies, and the availability of capital on favorable terms.

DISCUSSION

By converting rice fields into ponds, freshwater pond aquaculture has expanded significantly in certain regions of the country (Belton et al., 2011; Hernandez et al., 2017). Our results of the cost analysis showed that switching to fish farming is more expensive than continuing to grow rice. Feed is the primary factor in the total cost. According to previous research (Hossain et al., 2022; Mitra et al., 2022), feed is one of the most significant cost items for fish farming, and profitability is sometimes sensitive to feed price. In order to guarantee a profit from fish farming, it is necessary to implement a suitable policy to stabilize the price of feed. Our research also indicated that farmers can earn more money by shifting to aquaculture than by growing rice. Previous studies suggested that in order to maximize output, aquaculture makes smart use of available resources and farmland (Basudha and Ansari, 2014), which in turn can increase income. This disparity in earnings could be a major incentive for farmers to switch to aquaculture. Sattar (2019) argued that the farmers switched from rice to aquaculture because it was more profitable for them. Farmers may be switching from rice to aquaculture in response to a growing labor shortage caused by the out-migration of young men from rural areas (Hossain and Bayes, 2009). However, given the dietary habits of Bangladeshi households, rice cultivation cannot be completely converted to aquaculture. Due to the labor-intensive nature of rice farming, mechanization of rice transplanting and harvesting can reduce costs and increase profitability.

Our probit model results indicated that farmers who had access to a formal source of credit (bank) were more likely to engage in aquaculture than rice farming. According to Islam et al. (2015), having access to credit plays a role in deciding whether or not to adopt aquaculture. Aquaculture requires a larger financial investment than most other types of farming. Therefore, the greater the farmer's access to credit, the greater their enthusiasm in switching to aquaculture. Farmers who participated in training were more likely to switch to aquaculture from rice farming. According to Sarma et al. (2011), there is a strong association between education and adoption of fish farming practices. We also found that training has a positive effect on land shifting decisions. Training for farmers can be an effective method of raising their understanding of the relative financial viability of various farming methods and thereby assisting them in adjusting to the new circumstances.

Farmers whose main occupation is agriculture are more inclined to participate in aquaculture compared to farmers involved in alternative activities such as petty business or day labor. This may be due to the fact that respondents involved in agriculture are more familiar with conditions at the farm level. Additionally, our findings indicate that rice farming is no longer profitable. Consequently, they may have chosen to convert their land to fish farming. The adoption of aquaculture is substantially influenced by farm size and credit availability. Farmers with larger acreages can diversify their agricultural practices. Therefore, they are more likely to engage in aquaculture. According to previous research, farmers' land constraints make it difficult for them to adopt new technologies (Islam et al., 2015). Another indicator of farmers' socioeconomic status is the size of their farms. Farmers with larger plots of land tend to be more financially stable, and aquaculture typically necessitates a larger outlay of capital. Therefore, large farm size owners can invest in aquaculture.

The findings also indicated that aquaculture contributes significantly to the household income of farmers. In accordance with the findings of Rahman et al. (2011), aquaculture contributed to between 15 and 87% of the household income of the respondent farmers. The results also suggested that, due to a larger proportion of total income, fish farmers can afford to invest some of their earnings in additional revenue-generating endeavors.

CONCLUSION

Although rice farming has been crucial to food security and livelihood in Bangladesh, there has been a shift in recent decades away from large-scale rice farming and towards small-scale aquaculture. The study estimated the relative profitability of shifting cultivation and its underlying determinants. Compared to rice farming, raising fish is more lucrative in terms of gross return, gross margin, net return, and benefit-cost ratio. The potential for high net income in aquaculture may serve as a motivating factor for farmers to consider the introduction of aquaculture practices in their rice fields. The generation of extra income through aquaculture has the potential to make a positive contribution towards enhancing housing conditions, sanitation facilities, and educational opportunities within households. However, shifting decisions is not a simple process. When formulating policy, it is essential to strike a balance between shifted and non-shifted farmers. In the event that farmers decide to transition from rice cultivation to aquaculture, the government should enact policies that facilitate the shift in farming. The provision of adequate training facilities and a sufficient supply of capital could support the investment decisions of shifted farmers. Concerned stakeholders can initiate appropriate actions, such as the provision of credit to farmers on favorable terms. In-house training sessions can increase farmers' knowledge and awareness, allowing them to make the best decisions possible. Nevertheless, the excessive transformation of rice fields into aquaculture ponds has the potential to diminish the overall production of rice, thereby potentially disrupting the consumption patterns of households and jeopardizing the food security status of the entire country. Hence, it is imperative to strike a nuanced equilibrium between farmers who have shifted and those who have not made the shifting decision. The profitability of rice farming can be enhanced through the implementation of mechanization, which reduces the reliance on human labor, decreases production costs, and increases overall earnings.

Despite the useful information obtained, this research has a number of limitations. A weakness of this study is that it was conducted in only one location in Bangladesh with a small sample size. Consequently, generalization of the results may be restricted. The study used cross-sectional data from a single period. Future research may consider employing a multi-period panel survey to obtain a more accurate estimate of land-shifting decisions.

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