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Transformation from Rice Farming to Fish Farming in Selected Areas of Bangladesh: Profitability and Income Inequality Analysis

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Abstract

This study examined the relative profitability and income disparities between fully and partially transformed farmers in Tarakanda and Phulpur upazilas of Mymensingh district. A purposive random sampling technique was employed to select 120 farmers, evenly split between fully transformed and partially transformed groups. Using descriptive statistics, t-tests, the Gini coefficient, and Lorenz curve analysis, the study explored the differences between these two farmer groups. Results revealed that fully transformed farmers were younger (35-45 years) and had higher educational levels than their partially transformed counterparts. Fully transformed rice farmers were found to be significantly more profitable, with a notable difference in net returns. However, income inequality was higher among fully transformed farmers, as reflected by a Gini coefficient of 0.43 compared to 0.35 for partially transformed farmers. The study also identified lower profitability and labor intensity as key drivers for farmers transitioning from rice farming to fish farming.

Keywords: Agricultural transformation; Farm profitability; Income inequality; Gini coefficient

1. Introduction

Bangladesh is an agro-based country and is striving hard for rapid development of its economy. All sub-sectors (crops, fisheries, livestock and ***forestry) of agriculture have registered substantial growth.*** Bangladesh, which has a population of 169.11 million and occupies an area of 144.480 km^2, is one of the poorest and most populous nations in the world (BER 2022). Farming is the oldest and predominant occupation in Bangladesh. In Bangladesh, villages account for 76.75% of the total population, and agriculture employs 51.7% of the workforce (BBS 2022). In our country, the rate of contribution of this crucial agriculture sector accounts for about 11.50 % of GDP, and the growth rate of agricultural GDP accounts for about 2.20 per cent (BER 2022). The GDP growth rate of our country increases from 3.33% in 1973 to 7.5% in2022 (Microtrends,2022).

Rice is Bangladesh's largest crop and the main staple in Bangladesh; with an average per-capita consumption rate of 144.5 kg/year (Yunus et al.,2019) 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), and it accounts for 67.5 percent of the daily caloric intake (FAO,2021).Its contribution to agricultural GDP is about 70 percent while its share of national income is one–sixth.(Sayeed and Yunus,2018) and half of the rural employment (nearly 48%) (Rahman F et al, 2016).

Bangladesh has experienced a recent expansion of fish ponds, replacing miles of green fields with these ponds, despite the practice of fish cultivation for centuries (Sattar, 2019). Bangladesh's fishery and aquaculture industries are linked to economic growth, with additional investment in fish production potentially boosting the country's economy by

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providing food, income, and nutrition. The fisheries sector contributes 3.50 % to the national GDP, 26.50% to the agricultural GDP, and more than 2.0 % to all export revenues (DoF, 2022).Fisheries sector also contributed about two-thirds of animal protein(BBS, 2014) and income from fish culture is available year round(Rahman,2014) Bangladesh is blessed with access to numerous open water areas with a wide range of aquatic species. About 60 % (62.58 g/day/capita) of the daily dietary requirement for animal protein is provided by fish (Chakraborty, 2021). A full or part-time job in this sector provides a living for about two core which is 12 % of the entire population. It creates women employment 1.40 million which is 8.5 % of fisheries sector employment (DoF, 2015).

In Bangladesh, a particular agricultural sub-sector is growing due to the congenial geographical and climatic environment. In the past, most of the agricultural land was occupied by crops and other agricultural sub-sector. But the situation has been changing with the rapid population growth and technological advancement. Since a few decades, Bangladesh's scale of agricultural sub-sector land use change has been higher than at any other time in history.

Since the beginning of time, the people of Bangladesh have relied heavily on rice and fish. Over the passage of time rice production and fish farming sector are increasing. Besides, cultivable per person is currently declining drastically as a result of aggravated population expansion during the last 12 years, agricultural land has been declining at an average rate of about 1%. Recently, per availability of land is 0.17% per acre (Banglapedia,2021). As a result, farmers want to increase their productivity and income by using their small pieces of land efficiently use. So, they give more concentration on their productivity and income by changing their farming system which gives them more profit and income generation. Fish farming is more profitable for both consumption and commercial purposes. Most of people either small or large farmers fish farming is taken as a commercial enterprise. From the 1980s to the mid-1990s, some rice fields were converted into fish ponds and people started to produce fish for commercial purposes (Akteruzzaman, 2005). Fish farming offers a solution to boost the economy by contributing to food, income and nutrition. Besides rice farming in our country is labor intensive exception for land preparation, which is increasingly mechanized of the operations are done by male and female workers. Aquaculture-based crop production system is in practice in more than 25% of the low-lying paddy fields (Akteruzzaman, 2005). High input cost, low price of the product, syndication, increased labour scarcity, absence of mechanization of rice farming etc. reasons for transforming from rice land into fish farming. Few studies anticipated few studies anticipated the shift from rice to fish farming. Dehadrai (1992) stated that aquaculture in the rice field may save the time men and women spent in fish culture, though this effect is somewhat counterbalanced by the additional work required to manage both rice and fish. Sattar (2019) stated that a farmer's life experiences often encourage them to adopt more productive practices, yet one of the goals of changing farmers was to achieve high profits. This could be another motivation for agricultural households to shift from rice production to aquaculture. Over the past few decades, a rice-based farming system in Bangladesh has been diversifying and changing towards fish farming (Ahmed, Zander and Garnett, 2011).Over the past decades,paddy-beased farming systems in Bangladesh have been shifting toward aquaculture (Ahmed *et al,*2011;Dey *et al*., 2013,Rahman,2022).) It is fund from different studies the impact of converting rice land to fish farming on income disparity in the Mymensingh District. Ela *et al.,* (2017) stated that Only fish farming led to the highest income, followed by alternate rice farming and Rice cum fish farming . According to Palas *et al.,* (2015), commercial fish farming land was largely converted from cropland, with a small part from Khas (government-owned fallow land) and fallow land region. Freshwater pond aquaculture has grown rapidly in some regions of the country due to the conversion of rice fields into ponds (Belton et al., 2011). Previous research imply that aquaculture maximizes productivity by utilizing available resources and farmland (Basudha and Ansari, 2014), leading to increased income.

Profit motive was one of the major reason to shift rice farming to fish farming (Rahman *et al.,*2022). Government and non-government efforts have promoted aquaculture and fish cultivation in rice plots, but recent efforts have not been successful, though freshwater pond aquaculture has expanded in some areas, affecting agricultural households' land use and causing land conversion (Belton,2011;Gurung et al., 2016). Farmers are increasingly interested in fish culture over rice farming, leading to a trend of converting rice fields into fish plots. However, the reduction of rice plots is making farmers reluctant to continue farming. The fisheries sector increases the income of the farmers and it gives more stability of profitability due to it does not have the possibility of production loss. Income earned more from the fisheries sector helps farmers to lead a standard life.

Northern Bangladesh's aquaculture is profitable and feasible, with a high cost-benefit ratio that influences per-hectare net returns in all types of aquaculture (Islam et al. 2017).The decision to shift land towards small scale aquaculture is financially profitable. The study's purpose was to evaluated income of transforming farming system from rice farming to fish farming. That helps to examine the profitability of fished based farming system that creates any income disparities in rural areas of Bangladesh covering some areas of Mymensingh districts. The Farmers as well as the researchers and planners may be benefited from this study.

Objectives

- To compare the profitability of farms fully and partially transformed from rice farming to fish farming.
- To assess income inequality among fully and partially transformed farmers as a result of transitioning from rice farming to fish farming.

2. Methodology

The selection of a study area is a critical step in research, as it fundamentally influences the outcomes based on the objectives set forth. For this study, the area was chosen specifically for its high concentration of freshwater pond fish farming, a practice that has increasingly transformed traditional rice farming. The conversion of rice land to fish farming is most prevalent in the northern region of Bangladesh, particularly within Mymensingh District. Among the 12 Upazilas in this district, two were selected purposively for their significant prevalence of transformed agricultural practices: Tarakanda and Phulpur. Within each of the selected Upazilas, two Agricultural Blocks (ABs) were purposefully identified based on the extent of the transition from rice cultivation to fish farming. This focused approach ensures that the research captures areas characterized by notable shifts in farming methodologies. To collect relevant data and insights, respondents were chosen randomly from each of the designated blocks. The selection of Upazilas and Agricultural Blocks was carried out in consultation with local Extension Officers, who provided valuable information regarding the agricultural landscape. These officers also supplied a list of farmers who had transitioned from rice farming to fish farming. Utilizing this list, a total of 120 farmers were randomly selected through a robust sampling technique. The farmers were divided into two distinct groups: fully transformed farmers: (This group consists of individuals exclusively engaged in fish farming) and partially transformed farmer (This group includes farmers who practice both rice and fish farming). Each group comprised 60 farmers. The data was collected by the researcher herself with the aid of a pre-designed and pre-tested interview schedule. A Structured copies of questionnaire were appropriated in eliciting information from the farmer Data were collected from April to June 2022 to fulfill the objectives. Data was collected for the half-yearly season of mixed fish culture and Boro rice production. Concerning this study, secondary data were collected and used to supplement the study.

2.1. Analytical technique

Data were analyzed with a combination of tabular and statistical techniques. The tabular analysis is used because it is mostly understood and easy to use. Descriptive statistics were used for the assessment of the socio-demographic profile of farmers.The collected data was then analyzed using MS Excel (2010) and STATA (version 14.1).

The Gini coefficient or the Gini Index or Gini ratio is a measure of Statistical dispersion intended to represent the income distribution of a nation's residents and is the most used measure of inequality. The Lorenz curve and Gini coefficient are the most common methods of analyzing income distribution and income inequality, respectively (Thewissen, 2014). For income distribution and income inequality incomes of households fully transformed farmers and partially transformed farmers using the Lorenz curve and the Gini coefficient. Corrado Gini, an Italian statistician and sociologist, established the Gini coefficient and published it in his 1912 paper "Variability and Mutability" (Italian: Variability e mutabilitά) (Ceriani and Verme, 2011). The Gini ratio varies from zero (perfect equality) to one (perfect inequality). There is various method of deriving the Gini ratio. This approach effectively quantifies income distribution, providing a robust measure of income inequality (Slack and Rodrigue, 2009) and followed this equation:

$$\text{Gini Co-efficient, } G = \left| 1 - \sum_{k=1}^{k=n-1} (X_{k+1} - X_k)(Y_{k+1} + Y_k) \right| ,$$

Where G indicates the Gini value, X_k is the proportion of the share of households and Y_k is the proportion of their corresponding income. Always the value of the Gini coefficient is taken as positive. Gini ratio and Lorenz curve were drawn to determine the distribution of income and income inequality. To constract a Lorenz curve percentage of the populations are plotted against the cumulative percentage of the variable.

Cost and return analysis is the most popular tool for analyzing profitability among farm households. The current study calculates the profitability of fish farming and Boro rice cultivation using the following method. The typical profit equation was used to analyze the profitability of fish farming and Boro rice farming in the research locations. In this study, costs and returns analyses were done on both variable and total cost basis. To estimate the profitability of the fish production and Boro rice production, respondents used cost of variable inputs such as pond preparation, tillage, hired labor, seed, fingerlings, fertilizer, lime, Cowdung, irrigation, and pesticides, feed, electricity, neting and Interest on

operating capital were calculated. Land use cost and family labor cost were used to calculate as a fixed cost. The following equation (Π) was developed to assess the financial profitability of fish production and Boro rice production.

$$\Pi_i = \sum_{i=1}^{n} P_i Q_i - TC = \sum_{i=1}^{n} P_i Q_i - (VC + FC)$$

Where,

Πi = Profit from ith fish production and Boro rice production

Qi = Quantity of the ith product (kg/ha)

Pi = Average price of ith product (Tk./kg)

TC = Total cost (Tk./ha)

VC = Variable cost (Tk./ha)

FC = Fixed cost (Tk./ha)

i = 1, 2, 3, ……., n

Per hectare, the profitability of fish production and Boro rice production from the viewpoints of individual farmers was measured in terms of gross return, gross margin, and net return (Dillon and Hardakar,1993)

Gross return: Gross return was calculated by simply multiplying the total volume of output with its per unit of price in the harvesting period.

Net return: The analysis considered fixed costs (which included lending rent and family-supplied labour). Net margin was calculated by deducting all costs (Variable and Fixed) from gross return.

$$NR = TR - TC$$

Where, NR= Net Return, TR = Total Return, TC = Total Cost

Gross margin: A gross margin calculation was performed to measure the difference between total return and variable costs. The reason for utilizing gross margin analysis is that Bangladeshi farmers are more concerned with determining their return on variable costs.

$$GM = TR - TVC$$

Where, GM = Gross Margin, TR = Total Return, TVC = Total Variable Cost

Interest on operational capital was calculated using the opportunity cost principle. Rice production and fish farming costs were incurred over a six-month period, resulting in an annual interest rate of 10% on operating capital. Miah (1992) provided a standard formula for calculating interest on operational capital.

The formula for calculating Interest on Operating Capital (IOC) is Alit, where Al is the total investment divided by two, t is the total time span of a cycle, and i is the interest rate, which was 10% annually during the research period. Interest on operating capital was calculated by using the following formula :

$$\text{Interest on Operating Capital (IOC)} = Al \times i \times t$$

Where, Al = Total investment /2,

t = Total time period of investment

i= Interest rate which was 10% per year.

Undiscounted Benefit Cost Ratio (BCR).

The average return per taka spent on production is an important measure for determining profitability. The undiscounted BCR was determined as the ratio of total return to total cost. A benefit-cost ratio (BCR) is an indicator showing the relationship between the relative costs and benefits of a proposed project, expressed in monetary or qualitative terms. If a project has a BCR greater than 1.0, the project is expected to deliver a positive net present value to a firm and its investors.

$$BCR = TR/TC$$

Where, TR = Total return, TC = Total Cost

A paired t-test was conducted to check whether the net return of fully transformed and partially transformed farmers was significantly different or not.

3. Result and discussion

3.1. Age distribution

The age structure of the sample farmers was classified into five age groups according to HIES, 2016 (i) 15-24 years, (ii) 25-34 years, (iii) 35-44 years, (iv) 45-54 years, (v) 55-64 years. Table 1 displayed that the age structure of farmers and found that the majority (46.67%) of respondents who converted fully from rice farming to fish farming realized an extra profit. The majority (28.33%), followed by the age groups of 45-54 and 25-34, and the least (3.33%). The majority (48.33%) of farmers who partially transformed were aged 45-54, indicating that middle-aged farmers are more likely to realize comparative profitability and adapt to new farming practices.

Table 1 Age distribution of the respondents

Age group (Years)	**Fully transformed farmers**		**Partially transformed farmers**	
	Number	Percentage	Number	Percentage
15-24	2	3.33	4	6.67
25-34	10	16.67	9	15
35-44	28	46.67	14	23.33
45-54	17	28.33	29	48.33
55-64	3	5	4	6.67
Total	60	100	60	100

3.2. Educational status of the respondents

Table 2 showed that the highest portion of education level of fully transformed farmer was higher secondary school (33.33%). Again, the highest portion of education level of partially transformed farmer was higher primary school (36.67%).However, it was observed that this transformation is relatively low in the case of the farmers who received education above higher secondary.

Table 2 Educational status of the respondents

Educational Status	Fully transformed farmers		Partially transformed farmers	
	Number	Percentage	Number	Percentage
No Formal School	6	10	8	13.33
Primary	9	15	22	36.67
Secondary	18	30	15	25
Higher Secondary	20	33.33	11	18.33
Above higher secondary	7	11.67	5	8.33
Total	60	100	60	100

3.3. Family size of the respondents

A family is defined in this study as a group of people who share a kitchen and eat meals together. Farmers are divided into three categories based on their family size: small (≤ 4 members), medium (5-8 members), and large (<8 members). Table 3 exhibited that small-sized families account for the largest percentage (46%), followed by medium (31.67%) and large (21.67%)-sized families in the case of farmers who completely altered their farming practices from rice farming to fully transformed fish farmers. Large-sized families, on the other hand, account for the biggest share (51.67%), followed by small (13.33%) and medium-sized families of fish farmers who have switched to partial rice and fish farming.

Table 3 Family size of the respondents

Family size	Fully transformed farmers		Partially transformed farmers	
	Number	Percentage	Number	Percentage
Small	28	46	8	13.33
Medium	19	31.67	21	35
Large	13	21.67	31	51.67
Total	60	100	60	100

3.4. Farm Size in the study area

The sample farmers' farm size was defined as the sum of all types of land processed by them and subject to legal rights. The farm size was calculated using the following formula: Farm size = owned land (homestead + pond + garden + farm area + cultivable land) + (rented/mortgaged/leased-in land)-(rented/mortgage/leased-out land) (Taj, 2013). Table 4 revealed that the medium farm size was the greatest for fully changed fish farmers (51.67%), while the small farm size had the highest proportion of partially transformed farmers (46.67%).

Table 4 Distribution of farm size of the respondents

Category	Basis of categorization (acre)	Fully transformed farmers		Partially transformed farmers	
		Number	Percentage	Number	Percentage
Small	0-2.49	11	18.33	28	46.67
Medium	2.50-7.49	31	51.67	25	41.67
Large	≥ 7.50	18	30	7	11.67
		60	100	60	100

Table 5 illustrated that average cultivated land per farmer is 5.8 acres. Of this 5.8 acres, an average of 3.48 acres is used for fish farming, which makes up 60% of their total cultivated land. The remaining 2.32 acres is allocated for rice farming, accounting for 40% of their total cultivated land. That's means on average the partially transformed farmers gave a priority for, fish farming over rice farming, devoting more land to the former.

Table 5 Allocation of Land by partially transformed farmers

Number of the farmers	Average cultivated land (acre)	Average area under fish farming (acre)	Percentage (%)	Average area under rice farming (acre)	Percentage (%)
60	5.8	3.48	60	2.32	40

In several recent years, various institutions such as banks especially commercial and Krishi banks, NGOs are providing credit to the farmers. Financial capital denotes financial resources that people use to achieve their livelihood objectives. Table 6 displayed that most of the fully transformed fish farmers used their own funds for fish farming. It was found 74%of the farmers used their own funds and the rest 23%and 3%borrowed money from banks and NGOs. The fish farming sector has the potential to generate considerable amounts of financial capital for the resources of associated groups. The study also revealed that a large portion of the respondents who were farming partially transformed farmers utilized own capital for farming (59%) while 19% and 22% of them received from NGOs and banks, respectively.

Table 6 Sources of credit of the respondents

Source of credit	Fully transformed farmers		Partially transformed farmers	
	Number	Percentage	Number	Percentage
Own capital	44	73	35	59
NGOs	2	3	10	16
Bank	14	23	15	25
Total	60	100	60	100

3.5. Income distribution and inequality of the respondents

The analysis provides background information on the amount and sources of income earned by fully transformed farmers and partially transformed farmers. Table 7 depicts that the value of the Gini coefficient for partially transformed farmers income is smaller than for fully transformed farmers. There is an unequal distribution of fully transformed farmers to partially transformed farmers. The higher Gini coefficient (0.43) implies that the benefits associated with full transformation were not evenly shared among fully transformed farmers. Some farmers might have capitalized on these changes much more than others, resulting in a larger income disparity. The lower Gini coefficient (0.35) indicates a more balanced income distribution for partially transformed farmers. This could mean that the changes implemented are more inclusive, benefiting a broader range of farmers rather than concentrating wealth among a few. The income inequality of fully transformed farmers is higher than that of partially transformed farmers. Gurung *et al.,* (2016) agreed households that did not practice aquaculture had a lower Gini coefficient compared to those that did .

Table 7 Measurement of inequality of income of fully transformed farmers partially transformed farmers

Respondents	Gini coefficient
Fully transformed farmers	0.43
Partially transformed farmers	0.35

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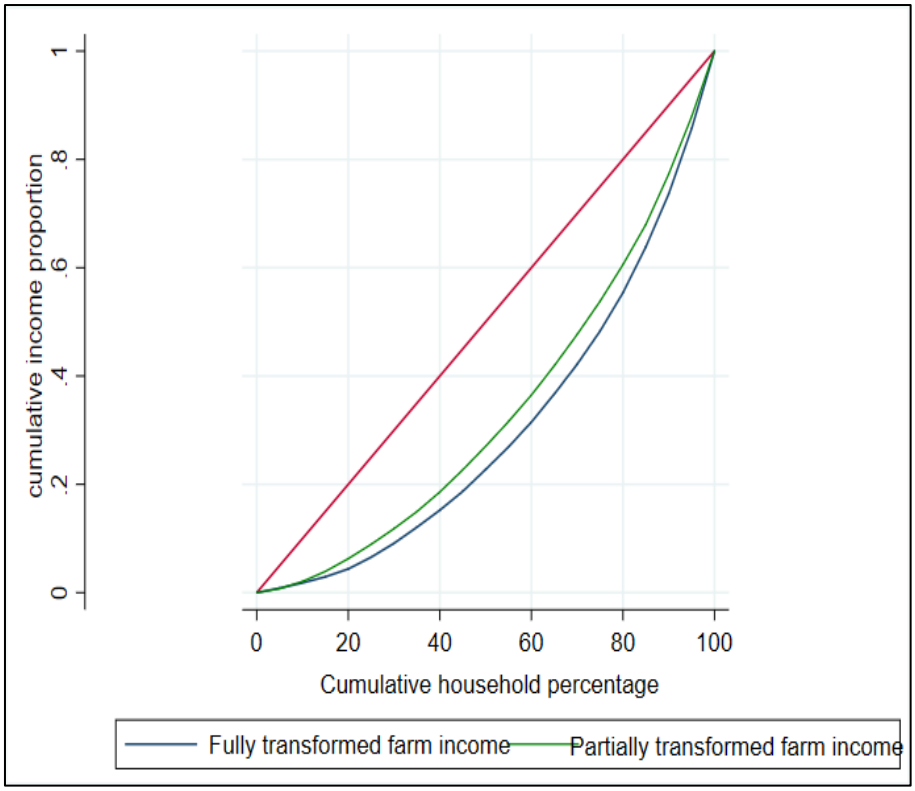

Figure 1 Lorenz curve for measuring income distribution and inequality of respondents

Figure 1 also showed a graphical representation of the Lorenz curve that is a useful method for measuring income inequity of fully transformed farmers and partially transformed farmers. To begin, the researcher created axes with the cumulative percentage of income (y-axis) and the cumulative households percentage (x-axis). Typically, the graph's axes are closed to form a box. The study found that the fully transformed farm income had a Lorenz curve that deviated from the line of equity, indicating rising inequality in agrarian communities. This results also supported by Gurang *et al.,* (2016).

3.6. Comparative Profitability Estimation

Fully transformed farmers (Fish Farming) had higher total variable costs (381,044 TK. or 4,084.34 USD) and total costs (476,044 TK. or 5102.62 USD).Partially transformed farmers (Fish Farming) had lower variable costs (307,599 TK. or 3,299.36 USD) and total costs (389,399 TK. or 4,176.76 USD).For rice farming, partially transformed farmers inured much lower costs, with variable costs at 72,492 TK. (777.03 USD) and total costs at 144,092 TK. (1,544.49 USD).Akter *et al.(2023*) also argued that fish farming is more expensive than rice cultivation.

The comparative profitability between fully transformed and partially transformed farmers, based on Table 10, revealed that significant differences in terms of gross return, net return, gross margin, and benefit-cost ratio (BCR). Fully transformed fish farmers earned a gross return of 1,005,000 TK (10,772.4 USD), while partially transformed fish farmers earned 718,560 TK (7,707.39 USD), indicating a 40% higher return for fully transformed fish farmers. For partially transformed rice farmers, the gross return was 161,610 TK (1,732.27 USD), which is substantially lower than both fish farming categories. Fully transformed fish farmers achieved a net return of 528,956 TK (5,669.78 USD), which is 60.6% higher than the net return of partially transformed fish farmers, at 329,161 TK (3,530.63 USD). Partially transformed rice farmers had a minimal net return of 17,518 TK (187.77 USD), demonstrating that rice farming is significantly less profitable compared to fish farming for partially transformed farmers. Fully transformed fish farmers had a gross margin of 623,956 TK (6,688.06 USD), which is 52% higher than the gross margin of partially transformed fish farmers at 410,961 TK (4,408.03 USD). Partially transformed rice farmers had a gross margin of only 89,118 TK (955.24 USD), further highlighting the lower profitability of rice farming compared to fish farming. The BCR on a full cost basis for fully transformed fish farmers was 2.11, indicating that for every 1 TK invested, they earned 2.11 TK in return. For partially transformed fish farmers, the BCR was 1.85, showing slightly lower efficiency compared to fully transformed farmers. For partially transformed rice farmers, the BCR was only 1.12, showing that rice farming barely generates a return over costs.

Fully transformed farmers in fish farming were significantly more profitable than partially transformed farmers. They achieved higher gross returns, net returns, gross margins, and a better BCR, indicating superior financial performance and better resource utilization. Rice farming, in contrast, is far less profitable for partially transformed farmers, with much lower returns and margins compared to fish farming.

Table 8 Per hectare (6 months) total cost of production

Items	**Fully transformed farmers**		**Partially transformed farmers**			
	Fish Farming		**Fish Farming**		**Rice Farming**	
	Total amount (TK.)	**Total amount (USD)**	**Total amount (TK.)**	**Total amount (USD)**	**Total amount (TK.)**	**Total amount (USD)**
A.Variable cost						
Hired labor cost	81000	868.22	54000	579.21	35400	379.45
Pond preparation/Tillage cost	20000	278.69	20000	278.69	9880	105.9
Fingerlings/seed cost	40500	145.32	33006	354.03	35.37	35.37
Feed cost	185280	$1985.97	150180	1610.85	-	-
Fertilizer cost						
Urea	4862	52.11	3960	42.48	3960	42.45
TSP	1675	17.95	1250	13.41	2350	25.19
MoP	-		-	-	960	10.29
Cowdung	1000	10.72	1000	10.72	2000	21.44
Mustard Oil cake	15309	164.09	14175	152.04	-	-
Lime	6630	71.07	3380	36.25	-	-
Irrigation	-	-	-	-	8000	85.75
Pesticide	-	-	-	-	3190	34.19
Electricity	7000	100.47	5500	58.99	-	-
Netting	6500	69.67	6500	69.72	-	-
IoC	18788	201.38	14648	152.12	3452	37
Total Variable cost	381044	4084.34	307599	3299.36	72492	777.03
B.Fixed cost						
Land Use cost	65000	697.2	65000	697.2	65000	697.2
Family labor cost	30000	321.56	16800	180.2	6600	70.74
Total Fixed cost	95000	1018.29	81800	877.4	71600	767.47
C.Total cost (A+B)	5102.62	467.5	389399	4176.76	144092	1544.49

Table 9 Relative profitability of Fully transformed farmers and Partially transformed farmers

Items	**Fully transformed farmers**		**Partially transformed farmers**			
	Fish Farming		Fish Farming		Rice Farming	
	Total amount (TK.)	Total amount (USD)	Total amount (TK.)	Total amount (USD)	Total amount (TK.)	Total amount (USD)
Gross Return	1005000	10772.4	718560	7707.390325	161610	1732.27
Net Return	528956	5669.775	329161	$3,530.63	17518	187.77
Gross Margin	623956	6688.061	410961	$4,408.03	89118	955.24
BCR on full cost basis	2.11		1.85		1.12	

t-test: Paired two sample for mean net return (Tk.)

To analyze t- statistics for the net return of the two samples like as transformed farmers and partially transformed farmers.

Null Hypothesis, H_0: There is no significant difference in net return (Tk.) within the two sample. Alternative hypothesis: There is a significant difference in net return (Tk.) within the two sample.

P(T<=t) two-tail 0.003

t Critical two-tail 2.022

The null hypothesis is rejected at the 1% significance level, indicating strong evidence that there is a significant difference in the mean net return between two sample

As a result, it showed that there is a significance difference between fully transformed farmer and partially transformed as their net return (Tk.).

3.7. Socio-economic factors for transforming rice farming to fish farming

The reasons outlined in table 10 revealed that a multifaceted perspective on why farmers are shifting from rice farming to fish farming. The top reason for transforming from rice farming to fish farming, with 93% of respondents citing it, is the higher profit in fish farming compared to rice farming. The predominant reason for the shift to fish farming was the potential for higher profits. Respondents perceived fish farming as more financially rewarding than rice farming. This could have been attributed to several factors, including better market prices for fish, lower production costs, and more favorable profit margins. The focus on profit underscored the economic viability of fish farming as a more attractive option for farmers. A significant 80% of respondents cited a lack of available labor for rice production as a critical factor in their decision to switch. This scarcity may have stemmed from urban migration, where younger individuals moved to cities for better employment opportunities, resulting in fewer workers available for agricultural tasks. Given that rice farming typically required substantial manual labor, this shortage complicated the sustainability of rice production, prompting farmers to consider less labor-intensive alternatives like fish farming. This phenomenon is also supported by the findings of (Hossain and Bayes, 2010 and Zhang, et al., 2014). About 78% of respondents highlighted the high costs of labor and inputs associated with rice production as a major reason for the transformation and ranked as a 3rd .This indicated that expenses such as labor, fertilizers, and irrigation were perceived to be greater than those for fish farming. Consequently, the economic burden may have driven farmers to seek more cost-effective alternatives, with fish farming presenting lower variable costs and different input requirements. About 72% of the respondent reported a shortage of good-quality seeds for rice production compared to the availability of fingerlings for fish farming. This difficulty in sourcing high-quality seeds could have adversely affected crop yields and profitability. In contrast, fingerlings were often more accessible, making fish farming a more appealing option for farmers facing challenges in obtaining quality seeds. The high demand for fish in the domestic market, noted by 65% of respondents, was a significant reason for the transformation. This robust market could have led to stable or rising prices, incentivizing farmers to engage in fish farming. Strong market demand provided assurance to farmers regarding the sale of their

products and potential profitability. Nearly half (49%) of respondents mentioned limited access to extension services as a factor in their decision. Extension services offered vital information, training, and resources to enhance agricultural practices. Insufficient access to these services for rice farming may have hindered farmers' ability to improve yields and manage crops effectively, prompting them to explore alternatives like fish farming, which may have required less external support. The potential for exporting fish to international markets was noted by 37% of respondents. Although this reason ranked lower, it remained relevant, indicating that access to export markets could have enhanced profitability and market reach for fish farmers. Opportunities for international sales provided additional income streams, making fish farming a compelling option for those seeking to expand their business.

Table 10 Reasons responsible for transforming from rice farming to fish farming according to the respondents

Reasons	No. of the respondents	Percentage of the respondents	Rank
Higher profit in fish farming compared to the farming of rice.	112	93	1st
Scarcity in the availability of labor in rice production.	97	80	2nd
High demand for fish in the domestic market.	78	65	5th
Exporting facility of fish to international markets.	45	37	7th
High cost of labor and inputs for rice production than fish farming	93	78	3rd
A shortage of good quality seeds is required in rice production than fingerlings in fish farming	87	72	4th
Less access to extension services.	59	49	6th

3.8. Problems and constraints of farmers

There is no doubt about that fish farming is a profitable venture but the farmers encountered some problems during their farming practices. The problems are classified into three categories: Economic Problems, Technical Problems and Social Problems Economic problems related to fish farming were identified as a lack of sufficient funds, lack of good quality fingerlings, seeds, lack of good quality fingerlings and high feed prices. Technical problems related to lack of scientific knowledge and technology, lack of Extension Services, disease proneness of fish and lack of market information. Social problems related to diseases proneness of fish and theft of fish.

Table 11 displays that About 87% of farmers complained that the high price of feed cost for fish farming and the high input (fertilizer, pesticides) cost of rice farming which was categorized as ranked 1st among all problems faced by the farmers. In the study area, the lack of good-quality fingerlings/seeds was another major problem for both farming systems. In the study area, the lack of good-quality fingerlings was another vital problem for the fish farming system. About 67%of farmers complained about the absence of quality fingerlings/seeds in the nearer. About 58% of farmers claimed that. Farmers often lack access to scientific knowledge and modern technologies that could enhance productivity and efficiency. It was ranked 3rd among the problems. Farmers are not economically solvent as fish farming is capital-intensive. They had to borrow money from commercial banks especially Bangladesh Krishi bank and Palli Sanchoy Bank and some local NGOs. But these NGOs are insufficient for providing loans for fish farming due to more capital requirements. It also happened with rice farming. About 48% of respondent farmers faced this problem. It was one of the crucial problems for the farmers in their farming system. About 41% of farmers have less insufficient knowledge of market information. A lack of information about market trends and prices limits farmers' ability to make informed decisions regarding sales and production strategies.About 33% of farmers complained that limited access to extension services hampers farmers' ability to receive guidance, training, and support for best practices in farming and ranked as 6th problem. Many farmers faced this problem as a social conflict and most of the time there was a conflict between the owner and the leasing person. About 28% of farmers claimed that they faced land conflict About 20% of fish farming farmers reported that their fish was attacked by viruses which cause losses in their production in the study areas. The theft of fish from ponds by thieves was one of the social problems in the study area. About 11% of farmers reported that the theft of fish is a concern for fish farmers, affecting their income and discouraging investment in fish farming.

Table 11 Some problems faced by the respondents

Name of Identified Problems	Percentage	Rank	Type
High feed price /high input cost	87	1st	Economical
Lack of good quality fingerlings/seeds	67	2rd	Economical
Lack of scientific knowledge and technology	58	3rd	Technical
Lack of sufficient Fund	48	4th	Economical
Lack of market information	41	5th	Technical
Lack of extension services	33	6th	Social
Land use conflicts	28	7th	Social
Disease proneness of fish	20	8th	Technical
Theft of fish	11	9th	Social

4. Conclusion

In this study, the Gini coefficients for fish farming and partial fish farming were 0.434 and 0.35, respectively. However, fully transformed farmers were more profitable The BCR of fully transformed fish farming was 2.11 greater than that of partially transformed fish farming. The fully transformed farm's BCR indicated that the farmers received a satisfactory net return on their investment. The result of this study showed that fully fish farming in the study area is highly feasible and profitable. It can therefore be recommended from the study that government and farm friendly institutions should support the fish farming. On average fully transformed farmers have highest BCR than partially transformed farmers. Both farmers faced economic, technical, and social problems. These issues included lack of funds, quality fingerlings, high feed prices, and disease. The results provide the following suggestions: proneness, and lack of market information. The results provide some suggestions. The Department of Agricultural Marketing should ensure and monitor prices, take strong action against syndicate groups, and establish a good marketing system with a support price scheme. Improve social awareness about scientific cultivation methods, provide farmers training, reorient extension information, improve pond management, and provide necessary facilities for poverty alleviation.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest in this work. The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

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