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*Article*

# Cost-benefit ratio analysis of freshwater aquaculture in selected area of Southern Bangladesh

Baadruzzoha Sarker[1*], Mohammed Mahbub Iqbal[2] and Lirong Yu Abit[3]

[1]Department of Accounting and Information Systems, Faculty of Business Studies, Jahangirnagar University, Savar, Dhaka-1342, Bangladesh
[2]Department of Fish Biology and Genetics, Faculty of Fisheries, Sylhet Agricultural University, Sylhet 3100, Bangladesh
[3]Department of Animal Science and Fishery, Faculty of Agricultural and Forestry Sciences, Universiti Putra Malaysia Bintulu Sarawak Campus, Jalan Nyabau 97008, Bintulu, Sarawak, Malaysia

*Corresponding author: Baadruzzoha Sarker, Department of Accounting and Information Systems, Faculty of Business Studies, Jahangirnagar University, Savar, Dhaka-1342, Bangladesh. E-mail: bstushar@gmail.com

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**Abstract:** The agriculture industry is widely believed to be essential to the nation's long-term growth and prosperity. In many ways, including via enhanced food security, employment, and economic growth, the agricultural sector as a whole and fisheries in particular have made significant contributions to enhancing people's health and well-being. A variety of measures may be used to determine the financial health of the fish farms. The purpose of this study was to estimate the financial viability of fish pond farming and to ascertain its advantages and disadvantages. From the Taltoli upazila in the Barguna area, sixty pond fish breeders were randomly selected. These figures allow us to calculate the gross cost of producing pond fish per hectare to be 1378806 BDT, the gross return to be 2125023 BDT, and the net return to be 746217 BDT. The findings of this study proved that pond fish farming was a profitable endeavor in the region that was being studied. The Cobb-Douglas production function was further employed in order to better comprehend the part that each variable in the production of pond fish plays. The majority of the taken into account factors were demonstrated to have a considerable impact on fish productivity. The returns on pond fish production were positively and statistically significantly impacted by four of the six parameters studied. To improve the management and cultivation of pond fish farming, certain recommendations were made.

**Keywords:** cost-benefit ratio; aquaculture; rural area; small scale farming; Bangladesh

## 1. Introduction

The fishing sector is very important and plays a vital part in Bangladesh's economy (Rahman *et al*., 2018; Shamsuzzaman *et al*., 2020). The provision of an appropriate quantity of fish can be expected to be significantly influenced by fish productivity (Rahman and Islam, 2020). Fishing is the main source of animal protein, and it also offers chances for employment to those living in both urban and rural locations (Ghose, 2014; Khanum *et al*., 2022).Most likely, enhanced pond fish production in Bangladesh will be able to satisfy the nation's growing domestic demand for fish (Palash *et al*., 2018). The Department of Fisheries (DoF) and various non-governmental groups are urging people to increase the quantity of fish that is generated in the nearby bodies of water, such as ponds, haors, baors, beds, and so on (NGOs) (Hossain, 2014; Rahman *et al*., 2018).

Pond fish farming's profitability often depends on how its inputs are applied, how it is managed, and other factors (Khan *et al*., 2021; Ragasa *et al*., 2022; Uddin and Akhi, 2014). Currently, some fish farmers in Bangladesh have realized the advantages of scientific aquaculture, and as a consequence, they have already put a number of cutting-edge approaches into practice to increase the quantity of fish that can be produced using pond fish culture (Ahammad *et al*., 2017; Ahmed and Garnett, 2011; Kumar *et al*., 2018; Little *et al*., 2016). Humans consume fish because of the high quality of fish as a food source (Tidwell and Allan, 2001). Fish muscle contains almost all of the macro- and micronutrients needed for human health (Ahmed *et al*., 2022; Nölle *et al*., 2021). A fish's whole bulk is made up of between 60 and 90 percent water, along with having a high percentage of protein, lipids, ash, and water- and fat-soluble vitamins, carbohydrates and nitrogenous, non-protein components (free amino acids, nucleotides, peptides etc.) (Hamli *et al*., 2021; Merdzhanova and Dobreva, 2020). Many people consider fish to be a delicious and essential source of protein (de Boer *et al*., 2020; Maulu *et al*., 2021).

The poor and the landless rely on a broad variety of fish species to satisfy their protein needs due to a lack of financial resources and the fact that some fish species are inexpensively accessible, particularly during specific months in the country (Heck *et al*., 2010). Poor rural households consume between 50 and 75 different kinds of fish year, according to a USAID study (Bogard *et al*., 2017). Numerous fish species have shown to be effective in addressing common health issues (Bogard *et al*., 2015; Gormaz *et al*., 2014; Kawarazuka and Béné, 2011). Fish that is dried has a greater protein level than fish that is fresh (Banna *et al*., 2022; Rasul *et al*., 2021). Marine fish are a great source of iodine since it is crucial for human health and a deficiency might result in the development of goiter (Herawati *et al*., 2021; Nerhus *et al*., 2018).

Bangladesh's fishing sector has risen significantly, opening up a wide range of career prospects (Hossain, 2014; Shamsuzzaman *et al*., 2020). There are 1316,000 individuals who make their living solely from fishing, including 3.08 million fish and shrimp producers, 800,000 inland fishermen, and 516,000 sea fishermen. In addition, a sizable population works in the promotion and processing of fishing products, whether these activities are industrial or non-industrial in nature (FRSS, 2019). Due to the richness of these resources, Bangladesh has developed a wide range of fish and shrimp processing businesses, hatcheries, research facilities, etc (Ali *et al*., 2018; Shamsuzzaman *et al*., 2017). Fisheries degrees are offered by several institutions, and each year hundreds of students get their degrees (Al-Asif *et al*., 2021).

Fish, shrimp, crabs, and other items from the fishing industry account for a sizeable portion of Bangladesh's export earnings. Shrimp was the most profitable export in terms of foreign currency after textiles (Rahman and Hossain, 2009). Considering the above-mentioned prospects and problems, this study was conducted to estimate the costs, returns, and profitability of pond fish fanning and identify the primary factors determining those costs, returns, and profits.

## 2. Materials and Methods

### 2.1. Study area and periods

The data were collected from Taltoli upazila,Barguna district of Bangladesh during July-August 2022 (Figure 1).

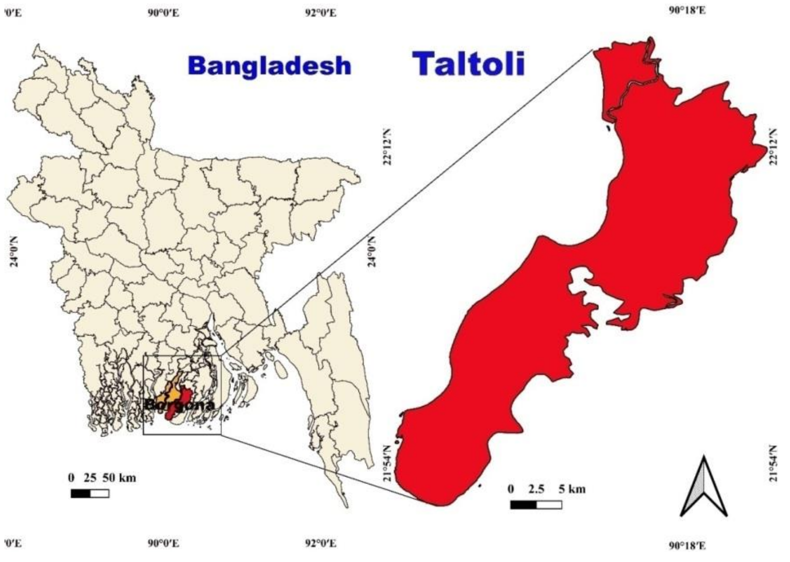


**Figure 1. Map of the study area.**

**2.2. Sampling techniques**

Considering the limited size of the population as well as the limitations of time, effort, and financial resources, a sample size of 60 farmers were randomly selected.

**2.3. Categories of farm household selection**

For this study, three types of farmers were chosen, small farmers (handling areas below one hectare, or below 2.47 acres), medium farmers (having areas between one hectare and three hectares, or between 2.47 and 7.49 acres), and large farmers (having areas above three hectares, or above 7.49 acres). For the current study, 60 farmers from the three categories indicated above were selected (Table 1).

**Table1. Sampling design and distribution of sample farmers.**

| Categories of farmers | Number of fish farmers |
|---|---|
| Small farmers | 40 |
| Medium farmers | 18 |
| Large farmers | 2 |
| All farmers | 60 |

**2.4. Processing statistical tabulation and analysis**

Once primary data was collected from the study area, it was summarized and double-checked for accuracy before tabulation. The processed data was exported to a MS Excel spreadsheet. Results were obtained by tabulating data and then analyzing and summarizing it using average, percentage, and ratio.

**2.5. Data tabulation, equations and analysis**

From the standpoint of individual farmers, the profitability of pond fish production was calculated per hectare in terms of gross return, gross margin, net return, and benefit cost ratio. The socio-demographic traits of the sample farmers, production rates, input usage, expenses, and profitability of pond fish farming were also examined. Below is a list of the equations and functions utilized in this investigation.

***Gross return***

The following equation was used to assess gross return by multiplying the entire volume of output of a firm by the average price throughout the harvesting season (Rahman *et al*., 2017).

$$GRi = \sum_{i=1}^{n} QiPi$$

Where $GR_i$=Gross return form it product (BDT/ha);
Qi= Quantity of the it product (BDT/kg);
$P_i$= average price of the it product (BDT/kg);
i=1,2,3............,n.

***Gross margin***

The estimated difference between total return and variable costs has been provided by gross margin,
GM=TR-VC
Where,
GM=Gross margin;
TR= Total return
VC= Variable cost

***Net return***

Fixed costs, land rent costs, interest on operating capital, etc. were taken into account in the net return analysis. After subtracting all costs, both fixed and variable, from the gross return, the net return was determined.

$$\pi = Py \sum_{i=1}^{n} (PxiXi) - TFC$$

$\pi$= net return (BDT/ha);
Py= per unit price of the product (BDT/kg)
Y=Quantity of the production per hectare (kg)
Pxi= per unit price of it inputs hectare (kg)

TFC=total fixed cost (BDT)
i=1,2,3.....,n (number of inputs)
In this study, cost and return analysis were done on both variable and total cost basis.
$\pi$= gross return- (Variable cost+ Fixed cost)
Here, $\pi$= profit per hectare
Gross return = Total production × per unit price
The cost of labor, fertilizer, fingerlings, feed, energy, manure, and lime are examples of variable expenses. Land usage charges and interest on operating capital are examples of fixed costs.

***BCR***

The BCR is a relative metric that is used to compare benefit to cost ratios. It is calculated as the ratio of gross returns to gross expenses, and the formula is presented below,
Benefit cost ratio= Gross benefit / Gross cost.

***Functional analysis***

The Cobb-Douglas production function model was used to do functional analysis in order to demonstrate the individual effects of input utilization and other relevant parameters on pond fish culture. The following model's format,

$Y=aX_1^{b1}X_2^{b2}X_3^{b3}X_4^{b4}X_5^{b5}X_6^{b6}e^n$

Where,
Y= Gross return, BDT/ha.
$X_1$= Human labor cost, BDT/ha
$X_2$= Fingerlings cost, BDT/ha
$X_3$= Fertilizer cost, BDT/ha
$X_4$= Manure cost, BDT/ha
$X_5$= Lime cost, BDT/ha
$X_6$= Feed cost, BDT/ha
In= Natural logarithm
$U_i$ = Disturbance term
a = Intercept
$b_i$= Co-efficient of the relevant variables

## 3. Results and Discussion

### 3.1. The price of seedlings

For fish farming, fingerlings of rui, catla, mrigle, silver carp, grass carp, mirror carp, and sharpunti were chosen. On average, fingerlings frequently cost 3/- BDT per piece. The cost of fingerlings per hectare for pond fish farming was 51870 BDT (Table 2). The previous study of Sharif and Al-Asif (2015), Al-Asif *et al*. (2014) discussed about the price of carp hatchlings and fingerlings at Jashore region, however, the seedlings prices taken into consideration for current study is relevantly reasonable for conducting any aquaculture operation.

**Table 2. Per hectare / year cost of fingerlings for fish production.**

| Species name | Stock/Ha | Price per fingerling | Fingerling price/ha (BDT) |
|---|---|---|---|
| Rui | 3705 | 4 | 14820 |
| Catla | 2470 | 6 | 14820 |
| Mrigal | 1729 | 2 | 3458 |
| Kalbasu | 2470 | 3 | 7410 |
| Sarputi | 1235 | 0.5 | 617.5 |
| Silver carp | 1235 | 0.5 | 617.5 |
| Carpio | 2470 | 0.5 | 1235 |
| Grass carp | 1976 | 4.5 | 8892 |
| | **17290** | **3** | **51870** |

### 3.2. Human labor cost

According to the type of operation, marketing and harvesting required the most human effort per hectare (402 man/days). The current study found, highest cost of human labor was for feed application (52.24%), followed by guarding (28.61%), harvesting fish (5.47%), Re-excavation (4.48 %), dike preparation (3.48 %), fertilizer and marketing are same as (1.99 %) , weeding (0.75%) and stocking of fingerlings and fencing are same as (0.5%). According to the research, fish feeding and guarding take up the majority of time (Table 3). One of the most significant inputs in the fish farming industry is labor (Ahmed, 2007). Study suggested that, most of labors are involved in pond management and feeding application works, while some of them are engaged with the security purpose, chemical application, and harvesting procedure (Ahmed, 2007; Asad *et al*., 2022; Jahan *et al*., 2021; Meah and Akther, 2021; Rahman *et al*., 2022; Saha *et al*., 2004; Sujan *et al*., 2021). However, the labor cost might be different due to geographical locations, availability, price of food, demand and supply, economic and food inflation (Guha and Tripathi, 2014; Taghizadeh-Hesary *et al*., 2019).

**Table 3. Distribution of labor cost per hectare per year in operation.**

| Cost item | Total labor (man days) | Cost (BDT) | % of total cost |
|---|---|---|---|
| Pond preparation (dike) | 14 | 2800 | 3.48 |
| Re-excavation/renovation | 18 | 3600 | 4.48 |
| Stocking of fingerlings | 2 | 400 | 0.50 |
| Fertilizer application | 8 | 1600 | 1.99 |
| Feed application | 210 | 42000 | 52.24 |
| Fencing/netting | 2 | 400 | 0.50 |
| Weeding | 3 | 600 | 0.75 |
| Guarding | 115 | 23000 | 28.61 |
| Harvesting | 22 | 4400 | 5.47 |
| Marketing | 8 | 1600 | 1.99 |
| | **402** | **80400** | **100** |

### 3.3. Cost on feed, fertilizer, chemicals, electivity and other additional cost

The fish farmers utilized an average of 741 and 741 kg of urea and TSP, respectively. It was found fish farmers used 20748 kg of ready feed per hectare. The average cost of watering and power for fishponds was 5700 BDT. The typical annual amount of manure used by fish farmers was 3000 kg. The typical annual amount of lime used by fish farmers was 400 kg. The average other cost per hectare per year for producing pond fish was 6350 BDT (Table 4). The most variable cost might be caused by the feeding cost, according to research on aquaculture management, although feeding plays a crucial part in the growth and output of farm setup (Ali *et al*., 2016; Islam *et al*., 2021; Rahman *et al*., 2016). Homemade feed and commercial feed are two management options that may be used on aquaculture farms, although most farmers choose to use commercial feed in their systems (Biswas *et al*., 2018; Vaumik *et al*., 2017; Zaman *et al*., 2017).

**Table 4. material input costs for fish farmer (every hectare).**

| Items of cost | Quantity (kg) | Price/kg | Total cost (BDT) |
|---|---|---|---|
| **Fertilizer** | | | |
| Urea | 741 | 20 | 14820 |
| TSP | 741 | 22 | 16302 |
| Feed | 20748 | 50 | 1037400 |
| Electricity | | | 5700 |
| Manure | 3000 | 15 | 45000 |
| Lime | 400 | 20 | 8000 |
| Others cost | | | 6350 |

### 3.4. Land use cost and interest on operating capital

In the study area pond rental value was calculated at 59933 BDT per hectare for one year. Interest on operation capital on an average represented 53031 BDT. In Bangladesh, leasing land is a typical method for aquaculture farming, however costs might vary depending on location, season, connection with landowner, inflation of food and currency, and other factors (Rahman *et al*., 2017; Sharif *et al*., 2016; Zaman *et al*., 2017).

### 3.5. Gross cost of pond fish production

The overall cost per hectare was 1378806 BDT with 5.83% to human labor; 3.76% to fingerlings; 75.24% to feed; 2.26% to fertilizer; 3.26% manure; 0.58% to lime; 0.41% to electricity; 0.46% other costs; 4.35% to land use cost and 3.85 % to interest on operational capital items (Table 5). This sort of analysis was conducted by the research of (Rahman *et al*., 2017) in Gazipur district, Northern Chattogram (Meah and Akther, 2021), Mymensingh and Jessore districts (Saha *et al*., 2004), Bagerhat district (Jahan *et al*., 2021).

**Table 5. Average gross costs of producing pond fish.**

| Cost items | Cost (BDT/ha) | Percent of cost |
|---|---|---|
| **Variable cost** | | |
| Human labour | 80400 | 5.83 |
| Fingerlings | 51870 | 3.76 |
| Feed | 1037400 | 75.24 |
| Fertilizer | 31122 | 2.26 |
| Manure | 45000 | 3.26 |
| Lime | 8000 | 0.58 |
| Electricity | 5700 | 0.41 |
| Other costs | 6350 | 0.46 |
| **Fixed cost** | | |
| Land use cost | 59933 | 4.35 |
| Interest on operating capital | 53031 | 3.85 |
| **Total** | **1378806** | **100** |

**Table 6. Average returns from pond fish production per hectare per year.**

| Yield | Quantity | Price/ kg | Value (BDT) |
|---|---|---|---|
| Sales | 10625 | 200 | 2125023 |

### 3.6. Gross return, margin, net return and return over per taka investment

The gross return revenue from fish farming in ponds was calculated 2125023 BDT (Table 6). The gross margin of pond fish production was estimated 859181 BDT. It was found that, per hectare net return was 746217 BDT. For every taka invested in pond fish farming, an income of 0.54 BDT was generated. It indicates that a total of 54 BDT was gained for an outlay of 100 BDT (Table 7). The similar findings of Rahman *et al*. (2017) revealed BRC from 2.87 to 3.28 in rice-fish integration.

**Table 7. Per hectare costs and economic returns of producing pond fish.**

| Particulars | Cost and returns (BDT/ha) |
|---|---|
| Yield (Y) kg | 10625 |
| Gross Return (GR), BDT | 2125023 |
| Total variable cost (TVC), BDT | 1265842 |
| Total fixed cost (TFC), BDT | 112964 |
| Total cost/Gross cost [TC= (TVC+TFC), BDT] | 1378806 |
| Gross Margin [GM=(GR-TVC), BDT] | 859181 |
| Net return [NR=(GR-TC), BDT] | 746217 |
| Return over per taka investment (NR/TC) | 0.54 |
| BCR (GR/TC) | 1.54 |

### 3.7. Cost-benefit analysis (BCR)

Pond fish aquaculture found successful since its benefit cost ratio (undiscounted) was 1.54 (Table 7). These results provide empirical support for the conclusion that the benefit cost ratio is greater than one, indicating that the study area has promising potential for pond fish development.

### 3.8. Factors affecting gross returns

To ascertain the impacts of resource consumption on the gross returns of pond fish production, the Cobb-Douglas production was used. In this study, fingerlings, feed, fertilizer, manure, lime, and human labor were used to produce pond fish. This section has examined how these factors affect gross costs and gross returns. The factors mentioned above were considered as a priori explanatory variables that controlled pond fish productivity. F-values were used to gauge the model's goodness of fit for various input types. This is one of the model's main properties. b) The multiple determination coefficient showed that the independent variables in the model were responsible for all output changes. c) Coefficients with enough degrees of freedom were assessed for significance at the 1% and 10% probability levels, and d) the stages of production were calculated using returns to scale, which was the total of all the production elasticities of different inputs. In the findings of Deng (2020) from Ethiopia suggested, ineffective fishing equipment, limited access to transportation, inadequate postharvest processing, low prices at the landing site, and an unsuitable market environment can all have an impact on gross returns. However, the kind and size of marketed fish, availability of fish in markets, fingerlings from good brood stock, labor availability in regional scale can be considered as some other limiting factors (Njagi, 2013; Vaumik *et al*., 2017).

### 3.8.1. Fingerlings cost ($X_1$)
Although the fingerlings' (X1) regression coefficient was negative for pond fish output, it was not statistically significant, indicating that other factors remained constant. 1% increase in cost of fingerings would increase gross return by -0.36 % (Table 8). This coefficient was, however, not statistically significant. While the coefficient of fingerling coast in rice-fish integration ranged between 0.573-0.601, which was far lower than the present findings (Rahman *et al*., 2017).

**Table 8. Estimated values of coefficient and related statistics of Cobb-Douglas production function model.**

| | Coefficient | Standard error | t value | Significant |
|---|---|---|---|---|
| Intercept | 8.94 | 7.43 | 1.20 | 0.23 |
| Fingerlings ($X_1$) | -0.36 | 0.36 | -1.00 | 0.32 |
| Feed ($X_2$) | 0.40 | 0.23 | 1.76 | 0.09 |
| Fertilizer ($X_3$) | -0.14 | 0.22 | -0.64 | 0.52 |
| Lime ($X_4$) | -0.28 | 0.16 | -1.77 | 0.08 |
| Labor ($X_5$) | 0.82 | 0.52 | 1.58 | 0.12 |
| Electricity ($X_6$) | -0.24 | 0.15 | -1.67 | 0.10 |
| Manure ($X_7$) | 0.08 | 0.11 | 0.73 | 0.47 |
| $R^2$ | 0.22 | | | |
| F | 2.15 | | | |
| Return to scale ( Σbi) | 0.27 | | | |

Note: ** Significance at 5% level.

### 3.8.2. Feed cost ($X_2$)
The regression coefficient of feed cost in pond fish production was positive and significant at the 1% level, indicating that, while other parameters remained constant, a 1% rise in feed cost would improve the gross return of pond fish production by 0.40% (Table 8). The feed cost coefficient in rice-fish integration ranged between 0.448-0.527, which was almost similar with the present study (Rahman *et al*., 2017).

### 3.8.3. Fertilizer cost ($X_3$)
At 1% level, the fertilizer cost coefficient was negative. It showed a 1% rise in the price of fertilizer. If all other variables remained constant, gross returns would go up by -0.14% (Table 8). This coefficient was, however, not statistically significant.

### 3.8.4. Lime cost ($X_4$)
When other parameters are held constant and the cost of lime is increased by 1%, the gross return on pond fish production decreases by -0.28%, according to the regression coefficient of lime cost, which was negative in pond fish production and significant at the 10% level (Table 8). This coefficient was, however, not statistically significant.

### 3.8.5. Human labor cost ($X_5$)
When other parameters are held constant, an increase in the cost of human labor by 1% would result in an increase in the gross return on pond fish production of 0.82%. This regression coefficient was positive for pond fish production and significant at the 1% level (Table 8). The human labor cost coefficient in rice-fish integration ranged between - 0.084 to - 0.174, which was far different with the present study (Rahman *et al*., 2017).

### 3.8.6. Electricity cost ($X_6$)

The regression coefficient of electricity cost was negative for pond fish production and significant at the 1% level, indicating that a 1% rise in the cost of this input would reduce the gross return of pond fish production by -0.24% while maintaining other variables constant (Table 8). This coefficient was, however, not statistically significant.

### 3.8.7. Manure cost ($X_7$)

If all other factors remained the same, the production coefficient of manure cost with a positive sign indicates that a 1% increase in manure would result in an increase in gross return of 0.08% (Table 8).

### 3.8.7. Value of $R^2$

The coefficient of multiple determinations $R^2$ was 0.82, meaning that explanatory factors accounted for around 82% of the return from pond fish farming. Those were incorporated into the model and showed that factors that were left out were responsible for 18% of the variance in pond fish farming (Table 8).

### 3.8.8. F-value

Given that the F-value of the equation was 41.71 and that this value was highly significant, it is clear that all of the explanatory variables included in the equation were crucial in explaining the variance in pond fish output. Consequently, it was appropriate to include independent factors (Table 8).

### 3.8.9. Returns to scale

The returns are directly estimated using the economic analysis. The estimated coefficients (input coefficients) of recognized explanatory variables are added to determine returns to scale. All of the equation's production coefficients (production elasticities) added up to 1.64 (Table 8). This demonstrated growing returns to scale in the production function. The gross return will increase by 1.64% if all the function's inputs are raised by 1%.

## 4. Conclusions

The current study has identified various important problems and restrictions that the selected producers faced when they were involved in fish farming. Producers were hampered by a lack of financing, working capital, scientific knowledge and methodologies, extension services, water during the dry season, fish theft, pond water toxicity, and other problems. In conclusion, it was discovered that most farmers had certain challenges and restrictions when it came to raising pond fish. In light of these discoveries, it is essential that these problems be fixed as completely as is practical in order to increase the area under fish farming and speed up its expansion.

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## Data availability

The data of this current investigation will be available upon valid request by any authority from the corresponding author.

## Conflict of interest

None to declare.

## Authors' contribution

Baadruzzoha Sarker: conceptualization, methodology, analysis and manuscript writing; Mohammed Mahbub Iqbal: conceptualization, methodology, reviewing and editing; Lirong Yu Abit: reviewing and editing. All authors have read and approved the final manuscript.

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