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Profit and loss dynamics of aquaculture farming

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ABSTRACT

Aquaculture's contribution has grown substantially in recent years, despite the fact that the price trend of several dominating species has remained constant when compared to input prices. Regardless of the fact that the nature of input usage varies considerably from farm to farm, productivity is improving but not to its maximum potential. Therefore, some farms are unable to make a profit by covering the production cost. For that purpose, this research evaluates the profit-making mechanisms and economic risk of pangasius and tilapia farming. A cross-sectional questionnaire-based survey was performed to collect data from 553 aquaculture farms in seven districts of Bangladesh, of which 275 were pangasius farms and 278 were tilapia farms. The financial performance of farms was evaluated using several descriptive and econometric analyses, while the Monte Carlo simulation method was employed to measure economic risk. Results revealed that the majority of pangasius and tilapia farms were profitable while a portion of farms was non-profitable. However, the lower market price of fish and inadequate inputs management were identified as the reasons for incurring loss at non-profit farms. Within the boundaries of economies of scale, this analysis also identified the optimum level of production for pangasius and tilapia. Meanwhile, sensitivity analysis suggested that lowering feed prices, maintaining feed quality, and raising fish prices would increase profitability on both farms. Besides, the simulation result showed that the risk of gaining profit was higher for pangasius than tilapia farming. Rational inputs use with proper extension support and increasing the output price to a reasonable limit would make pangasius and tilapia farming a more profitable venture.

1. Introduction

Aquaculture sectors play significant roles in providing food, nutrition, income, and employment worldwide (FAO, 2020; Mitra et al., 2019; Belton et al., 2018). Global aquaculture production has risen more than five times from 1990 to 2018, while the production of capture fisheries has remained relatively stagnant (FAO, 2020). Besides, per capita fish consumption has been increased by 1.5% over the last five decades as much as the population growth (FAO, 2020); hence the improvement of aquaculture production is the staple solution to meet the rising demand for the consumption and protein requirement (Zander and Feucht, 2020; FAO, 2020; Béné et al., 2016; Clark and Tilman, 2017). Currently, the majority of aquaculture production takes place in Asian countries, namely: China, India, Indonesia, Vietnam, and Bangladesh, which accounted for approximately 89% of total global production (FAO, 2020).

Although total aquaculture production has surged in recent decades, per-hectare productivity in many countries has not yet reached the desired level. Theoretically, the main goal of every aquaculture farm is to maximize profits by utilizing available resources, technology, and production methods (Shawon et al., 2018; Greenfeld et al., 2019). Therefore, fish farmers must mix both inputs and output in such a rational way that maximizes their profit. One of the ways to enhance profitability is to increase fish production per unit of pond area and most of the commercial aquaculture farmers try to follow intensive or semi-intensive culture systems for increasing productivity. Intensive or semi-intensive commercial aquaculture production is attributed to several production factors such as fingerling, feed, labor, water cleaning

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substance, etc. (Alam et al., 2012; Pomeroy et al., 2014). Among them, commercial pelleted feeds are one of the most important inputs in the production process; and the contribution of commercial pelleted feeds to aquaculture productivity is immense (Asche et al., 1999; Rimmer et al., 2013; Dey et al., 2013; Khan et al., 2018; Munguti et al., 2021; Islam et al., 2020). This significance is underscored by the fact that fish feed accounts for more than 70% of total costs (Belton et al., 2011). However, due to contamination in feed production, the quality of feed has decreased in recent years (Pietsch, 2020; Kong et al., 2020). On the flipside, the demand for feed ingredients grew as aquaculture production increased expeditiously owing to the use of commercial feeds (Rana et al., 2009; Sarker et al., 2016). Given the importance of commercial pelleted feeds, the ingredients price is quite high in the market, making the feed price higher, which in turn, affects the production cost and return of the farmers (Khan et al., 2021a; Hossain et al., 2022a, 2022b).

Carps, pangasius, and tilapia are just a few of the many aquaculture species that make a significant contribution to Asian aquaculture production (FAO, 2020). However, pangasius and tilapia are important species to be cultured in ponds since they contribute significantly to employment and income generation, protein for the poor, and foreign export earnings in the global South (Khan et al., 2021b; Belton et al., 2018; Marschke and Wilkings, 2014). Despite this, pangasius and tilapia farming has faced several obstacles in recent years, including rising feed costs and declining feed quality, both of which have a detrimental impact on production (Singh et al., 2015; Ngoc et al., 2016; Nguyen et al., 2016; Mukta et al., 2019; Mussa et al., 2020).

Additionally, the market price of pangasius and tilapia is considerably lower than that of the major carps (Hossain et al., 2022a), which is a source of concern for fish farmers. Carp species, on the other hand, are more popular among farmers, have a higher market demand and value, and can be farmed in a pond with little effort (Dey et al., 2010a). These factors frequently encourage farmers to switch to the culture of alternative high-value species, making low-value fishes inaccessible to the poor. Despite having higher productivity than other low-value cultured species, a considerable number of pangasius and tilapia farms have failed to achieve profit consecutively due to major interruptions in the production process, inefficient inputs utilization, lower market price, and higher operational capital (Prodhan and Khan, 2018). For these reasons, many pangasius and tilapia farmers are facing various kinds of production and financial risks.

However, this study considers Bangladesh as a case country because the inland freshwater aquaculture of Bangladesh is mainly dominated by pangasius and tilapia, and has great export potentiality in the world market (Fisheries Resources Survey System (FRSS), 2020). Besides, pangasius and tilapia gained popularity among farmers as quick-growing, high-yielding fishes with a greater reaction to external feeding, suitable for freshwater, and dealing with a variety of culture techniques (Khan et al., 2021b). The per hectare productivity of pangasius and tilapia farming is much higher than carps, although it requires higher operational capital (Ahmed and Toufique, 2014). Additionally, pangasius and tilapia can be stocked at higher densities in ponds than other aquaculture species (Rahman et al., 2012; Khan, 2012; Alam, 2011). Besides, the low market price of pangasius and tilapia than carps (Fig. 1) ensures poor consumers' protein requirements efficiently at a low cost. As a result, pangasius and tilapia farming have become important aquaculture industries in Bangladesh, gaining popularity among fish farmers and thus being considered for this study.

Nonetheless, farmers' profits have been skewed as a result of the combined effect of high input prices and low market value of fish, and some farms are even losing money. Besides, most farmers believe that adding more supplementary feed and other inputs will increase production and profit. However, obtaining these inputs comes at a significant expense, which further has a negative impact on farm profitability and raises the concern of economic risk.

The preceding discussion presents a number of intriguing questions: What percentage of pangasius and tilapia fish producers in Bangladesh are non-profit? What are the reasons that make them non-profitable? And how can they be made financially viable? To answer these questions, we gathered primary data from Bangladesh to look at the cost structure of profit and non-profit farms, the inputs used by profit and non-profit farms, strategies to improve non-profit farm profitability, economies of scale theory, profit sensitivity to feed and fish price changes, and the economic risk of pangasius and tilapia farming in Bangladesh. These have been examined by traditional tools of analyzing farm-level surveyed data on Bangladesh's aquaculture industry. Knowing how to strengthen farm performance, as well as how to reduce economic risk, is critical for developing the best plan for reducing return variability and risk in pangasius and tilapia farming. Thus, the empirical findings of this study will produce meaningful information for fish farmers on minimizing both return variability and risk and improving profitability, which may enhance financial and institutionally based policies for sustainable pangasius and tilapia farming in Bangladesh and other South Asian countries with similar production and economic background.

Several studies have been conducted related to the productivity and profitability of pangasius and tilapia (Mukta et al., 2019; Ali et al., 2013; Jahan et al., 2016). Khan et al. (2018) found that a significant production risk exists in the pangasius farming of Bangladesh. Alam et al. (2019) found capital and credit have a significant risk-reducing effect on tilapia's production risk in Bangladesh. Prodhan and Khan (2018) conducted research considering the adoption of scientific aquaculture management practices and found that by doing so fish farmers can boost their farm productivity and profitability. However, no research has been uncovered in Bangladesh that identifies techniques for turning non-

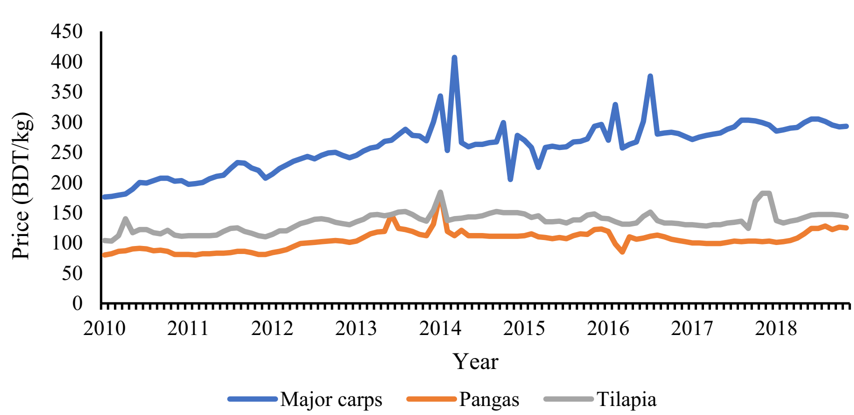

Fig. 1. Average price trend of pangasius, tilapia, and major carps during 2010–2019.
Source: DAM (2019).

profitable farms profitable while taking into account economic risk and economies of scale in pangasius and tilapia farming.

The rest of the paper is organized as follows: Section 2 describes the materials, methods, and data. Section 3 provides insights into empirical results and discussion. Finally, section 4 concludes the study along with some policy recommendations.

2. Materials and methods

2.1. Study areas and data collection

The data used for this study was collected from purposively selected seven districts (administrative areas) of Bangladesh namely, Mymensingh, Cumilla, Bogura, Chattogram, Khulna, Jashore, and Bhola. The sampling areas are shown in Fig. 2. These selected districts have produced a significant portion of Bangladesh's overall pangasius and tilapia output, accounting for 60% of pangasius and 35% of tilapia production (DoF, 2019). For this study, a total of 553 farms were randomly interviewed, consisting of 275 pangasius and 278 tilapia farms from the listed farmers of the local Department of Fisheries office (Table 1).

The selected farmers were interviewed using a predesigned and pretested interview schedule. The draft interview schedule was pre-tested with ten farmers to improve, rearrange, and modify in light of the information received during the pre-test. The interview schedule was prepared and organized to generate information on farming practices, price, and quantity of inputs and outputs. Fifteen focus group discussions (FGDs) with seven to nine farmers were held at the village level to guarantee the reliability and cross-check of obtained data. We actively communicate with farmers for cross-checking when we find any inconsistencies between FGD findings and primary data.

Table 1
District-wise sample size.

Districts name	Pangasius farm (number)	Tilapia farm (number)
Mymensingh	113	85
Cumilla	47	84
Bogura	48	18
Chattogram	10	47
Khulna	10	5
Jashore	21	22
Bhola	26	17
Total	275	278

2.2. Private economic analysis of farms

An economic analysis was conducted to determine the viability of pangasius and tilapia fish production per hectare. Table 2 shows the equation used to measure the profitability of pangasius and tilapia farming in terms of gross return, gross margin, net return, benefit-cost ratio (BCR), breakeven price (BEP), and breakeven yield (BEY). The economic analysis was based on the sales price of fish received by the farmers and the price paid for purchasing production inputs. In addition, the average price of consumed, gifted, and discarded fish was considered while calculating the profit. All numerical value of data was considered as USD while 1 USD = BDT 79.31 during the production period of 2017.

It should be noted that not all of the farms considered are profitable, thus farms that are losing revenue were recognized and segregated from profitable farms using their computed BCR. The two most effective ways were found to reach these non-profit farms to their breakeven point. These are; (i) cost minimization and (ii) productivity maximization. To reduce production costs, a two-factor *t*-test was performed using STATA software for comparing the costs of non-profit farms with profit farms.

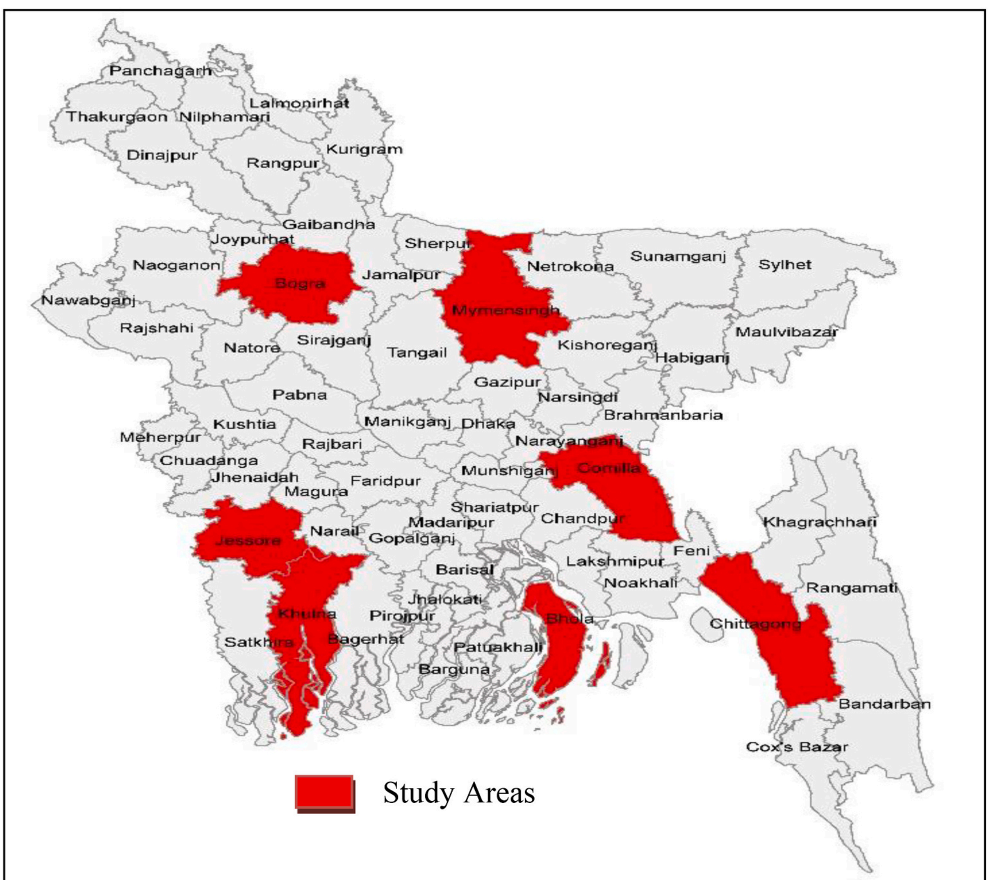

Fig. 2. Map indicating selected districts in Bangladesh.

Table 2
The equations to estimate the profitability of pangasius and tilapia farming (ha^{-1}).

Particulars	Equation
Variable costs	= Cost of labor (family [a] + hired), fingerling, feed, fertilizer, water clean, and miscellaneous (harvesting, electricity, torchlight, rope, umbrella, commission for the caretaker, mobile bill, and repair of guard shed)
Fixed cost	= Land use cost + depreciation cost
Total cost	= Variable cost+ fixed cost
Depreciation cost (Straight line basis)	= (Purchase price-salvage value)/economic life span
Gross return (GR)	= Total production × average sale price
Gross margin (GM)	= Gross return – total variable cost
Net return or profit (Π)	= Gross return – total cost
Benefit-Cost Ratio (BCR)	= Gross return/ total cost
Breakeven Price (BEP)	= FC [b]/ (Volume of production) + Variable cost per kg
Breakeven Yield (BEY)	= FC/ (Sales price per kg- variable cost per kg)

[a] Family labor was considered the opportunity cost for the farmer. However, it was difficult to quantify the family labor precisely because family labor was used for a different purpose, and farmers did not memorize how much they spent on fish farming. [b] Fixed cost.

After doing so, a newly modified BEY was calculated by using this minimized cost and output price of non-profit farms to determine the required amount of yield to reach an effective breakeven point.

2.3. Sensitivity analysis

Sensitivity analyses were performed to assess how farmers can earn financial benefits in different situations (reducing feed price and increasing output price). To conduct the sensitivity analysis, the base case of BCR, gross profit margin, net profit margin, breakeven price, variable cost per kg of fish production, and benefit from per kg fish were defined; say the feed price at a particular case was input value for which the sensitivity is to be measured keeping other inputs of the model constant. Then the changing value of the base cases at a new value of the feed price was calculated. In the same process, following the previous study of Hossain et al. (2022b), five scenarios were calculated such as feed price decreased by 10%; feed price reduced by 20%; fish price increased by 10%; feed price declined by 5% and the fish price increased by 5% simultaneously; feed price reduced by 10% and the fish price increased by 10% simultaneously.

2.4. Economic risk analysis

Commercial freshwater pangasius and tilapia involve uncertainties related to three main specific areas such as yield, price of feed, and fish price. The Monte Carlo simulation method was employed to assess the risk associated with these uncertain variables of aquaculture farming. The uncertain variables were selected following the previous studies (David et al., 2018; Ngoc et al., 2016). This method allows for all the uncertain inputs, labeled stochastic variables, to vary simultaneously following a probability distribution and covariance that have been specified for each variable (Hardaker et al., 2004). In this way, all the possible outcomes are taken into account. The Oracle® Crystal Ball software was used to simulate profit using 1000 iterations (Engle, 2010). Several studies have used this model to analyze the risk of fish farming (e.g., David et al., 2018; Ngoc et al., 2016; Valderrama et al., 2016; Kam and Leung, 2008), and rice farming (e.g., Kadigi et al., 2020; Taghizadeh et al., 2020).

The stochastic input variables were productivity, output price, and feed price, which are described by triangular distribution. We used the most likely, minimum, and maximum values derived from the mean, minimum, and maximum values, respectively, for triangular distributions (Vose, 2008). The simulation model of pangasius and tilapia profit were estimated by entering the stochastic feed price, yield, and output price into the simulation model. Table 3 represented the descriptive statistics of each risk factor from the Monte Carlo simulation.

3. Results and discussions

3.1. Distribution of profit and non-profit farms

In the research areas, aquaculture farms used both home-supplied and commercial inputs. Farmers had to pay cash for purchased inputs, and these items were valued at the prevailing local market rates. The opportunity cost and rental value principles were used to calculate the cost of family labor and the cost of owning a pond, respectively. Thus, both cash and non-cash costs were included in the overall production costs. The cost items were classified into two categories: variable cost and fixed cost. Human labor, fingerlings, feed, fertilizer, water cleaning, and other miscellaneous costs were considered variable costs. At the same time, the lease value of land and depreciation of equipment in the pangasius and tilapia production process was recognized as fixed cost components. All input costs and output prices were taken into account for one production year to calculate the per hectare cost and return. In this study, farms were divided into two: profit and non-profit farms. Profit and non-profit farms were determined after calculating the net benefit in a production year. The profitability analysis results showed that 78.55% of pangasius farms were profitable, while 21.45% were non-profitable among selected farms (Fig. 3). In the same way, 71.58% of tilapia farms were profitable, whereas 28.42% were non-profit farms.

3.2. Cost structure of profit and non-profit farms

3.2.1. Variable cost

Regarding variable cost analysis, labor cost was found about 8.8% and 10.5% of total production cost for pangasius and tilapia profit farms, respectively (Fig. 4). A similar result was found in the study conducted by Mukta et al. (2019) and Ahmed et al. (2010). In the case of non-profit farms, the average human labor cost was USD 3627.93 ha^{-1} and USD 3324.07 ha^{-1} for pangasius and tilapia farming, respectively, which was about double that of the profit farms (Table 4). To ensure the sustainability and progress of the production, sound quality fingerlings are prerequisites. Farmers usually bought fingerlings from hatcheries, fry collectors, and neighboring farmers. However, only the hatchery can guarantee the quality of fingerlings. The cost of fingerlings varies according to the quality, size, species, and availability. Farmers in the study areas usually purchased 3–5-in.-sized fingerlings. Sometimes, they also purchased fry, reared in a nursery pond, and released to the main pond when it reached the fingerling size. However, fingerlings cost grasped 9.2% and 11.7% of total production cost for pangasius and tilapia profit farms, respectively (Fig. 4). This finding was similar to Mukta et al. (2019), Phiri and Yuan (2018), and Ahmed et al. (2010). They found that fingerlings account for 8–10% of total production costs in pangasius and tilapia culture. Non-profit farms, on the other hand, released greater numbers of fingerlings in the pond to increase productivity, as seen by our findings that non-profit pangasius farms stocked a greater number of fingerlings per hectare than profit farms (Table 5). The higher number of fingerlings stocked ultimately pushes up the production cost of non-profit farms than the profit farms (Table 4). Despite the fact that non-profit farms' fingerling costs are significantly greater, non-profit farms' fingerling costs contributed less to the overall cost for both pangasius and tilapia (Fig. 4). This might be

Table 3
Risk factors for pangasius and tilapia farming.

Risk factor	Pangasius	Tilapia
Price of feed (USD kg^{-1})	0.49 ± 0.07	0.53 ± 0.07
Productivity (kg ha^{-1})	28,377.47 ± 10,221	19,162.80 ± 8204.89
Output price (USD kg^{-1})	1.22 ± 0.17	1.42 ± 0.20

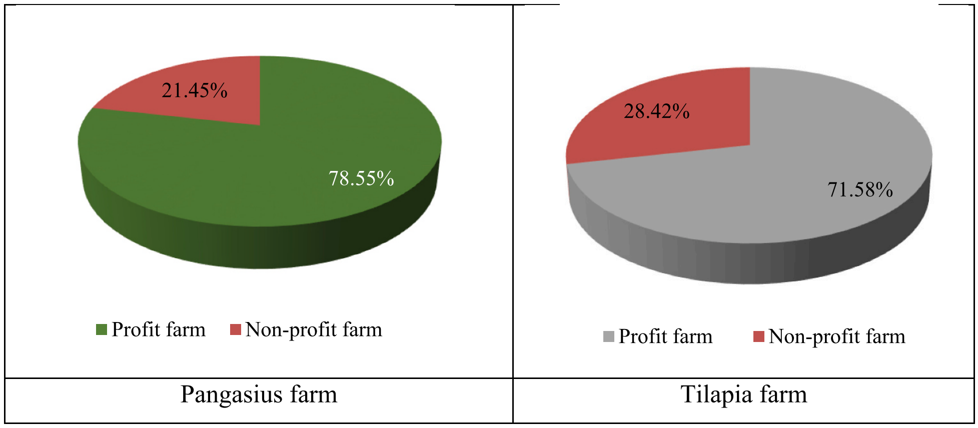

Fig. 3. Percentage share of profit and non-profit pangasius and tilapia fish farm.

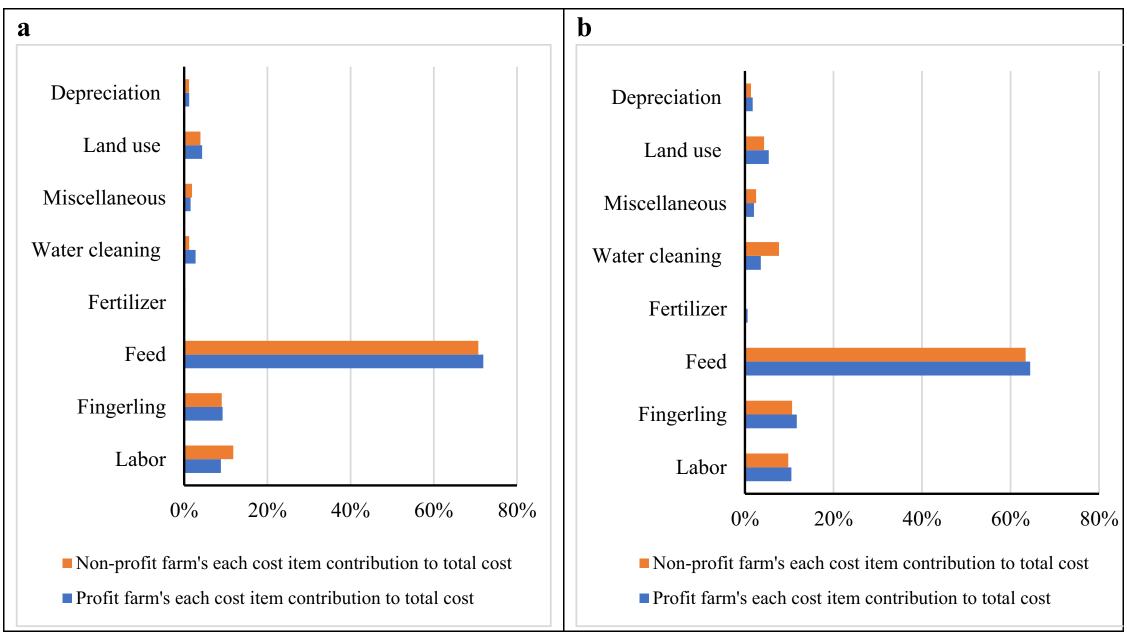

Fig. 4. Cost distribution of aquaculture farms (a. pangasius; b. tilapia).

due to the fact that non-profit farms are brushing aside fingerling attributes such as fingerling quality, which dwindles productivity. High-quality fingerlings can boost productivity, whereas low-quality fingerlings might result in revenue losses due to various diseases and a lower growth rate. As a result, non-profit farms should place a greater emphasis not just on optimal stocking density mixing, but also on fingerling quality.

Feed and its quality management are essential inputs for aquaculture production. We observed from the field survey that the majority of farmers utilized commercial pelleted feeds in their pond, while just a handful used homemade feed produced from rice bran, oil cake, wheat bran, maize, fish meal, and other ingredients. Among all cost items, the feed cost accounted for 71.9% and 64.4% of total production cost for profit farms while 70.7% and 63.4% for pangasius and tilapia non-profit farms, respectively (Fig. 4). The finding of this study is consistent with the study of Mukta et al. (2019), Rahman et al. (2019), Hernandez et al. (2018), Prodhan and Khan (2018), and Phiri and Yuan (2018), where they observed that feed cost was the major operational cost for most fish farms, accounting for 60–79% of the variable cost. Even though the share of feed costs to total costs is lower for non-profit farmers, Table 4 shows that non-profit farms spend more on feed, resulting in higher production costs and skewed profit. This suggests that non-profit farmers incautiously used feed in their ponds, which must be met in order to become profitable. Besides, most of the time, farmers used inorganic fertilizers like Urea and TSP in pangasius and tilapia pond. In the study areas, the average fertilizer cost in profit farms was USD 43.78 ha^{-1} and USD 123.88 ha^{-1} for pangasius and tilapia, respectively. In the case of non-profit farms, the average fertilizer cost was USD 91.79 ha^{-1} for pangasius and USD 86.13 ha^{-1} for tilapia farms (Table 4). Pond water becomes unsound due to the overuse of commercial pellet feed and fertilizer. To overcome this problem, the fish farmers cleaned and dried the pond before releasing fingerlings at every new culture cycle. The farmers take different actions to maintain sound water quality to enhance the fish growth, like application of lime, salt, aqua clean, gerolux, potash, bleaching powder, zeolite, etc. Results revealed that both profit and non-profit tilapia farms incur more costs for cleaning water than pangasius farms. Farmers also spend some additional costs to maintain their farms designated as miscellaneous costs; it varied 1.6–2.5% of total production cost.

3.2.2. *Fixed cost*

Land use cost was the most important fixed cost item. Furthermore,

Table 4
Private economic analysis of pangasius and tilapia farming (USD ha^{-1}).

Items	Pangasius		Tilapia	
	Profit farm	Non-profit farm	Profit farm	Non-profit farm
Variable cost				
Labor	2331.31	3628.00	2069.59	3324.07
Fingerling	2441.51	2776.80	2314.67	3613.80
Feed	18,997.33	21,741.54	12,721.36	21,517.99
Fertilizer cost	43.78	91.79	120.09	86.13
Water cleaning cost	729.26	367.84	706.63	2608.56
Miscellaneous cost	411.36	577.18	405.18	852.48
Total variable cost	24,954.56	29,183.15	18,337.54	26,300.48
Fixed cost				
Land use cost	1139.12	1203.13	1060.46	1463.30
Depreciation cost	321.69	363.85	344.56	461.18
Total cost	26,415.37	30,750.13	19,742.55	33,927.51
Productivity (kg)	27,070.3	21,169.68	17,281.62	16,679.56
Return (USD)	32,529.54	25,280.85	24,019.34	25,445.63
Net return (USD)	6114.18	−5469.30	4276.79	−8481.88
BCR	1.26	0.82	1.23	0.75
BEP (USD kg^{-1})	1.00	1.58	1.19	1.39
BEY (kg ha^{-1})	21,973.43	25,671.53	13,992.89	27,017.96

Table 5
Inputs use differences of profit and non-profit farms.

Particulars	Pangasius		Tilapia	
	Difference	t-value	Difference	t-value
Labor (man-days ha^{-1})	−228.93	−0.29	−190.22	1.17
Fingerling (number ha^{-1})	7133***	3.92	5082***	3.72
Feed (kg ha^{-1})	2315.11***	2.97	3547.25***	3.88
Water cleaning cost (USD ha^{-1})	−18.69	−0.43	61.82**	2.31
Fertilizer cost (USD ha^{-1})	48.01**	2.03	−33.97	−0.84
Miscellaneous cost (USD ha^{-1})	4.78***	5.39	1.40**	2.12
Total variable cost (USD ha^{-1})	4354.69***	2.61	6694.51***	4.49

Note: Positive value indicate non-profit farm's input use is greater than profit farm's and vice versa.
***, and ** indicate the significance at 1% and 5% levels, respectively.

due to the depreciation of tangible assets, the farm loses some value. Considering pangasius and tilapia profit farms, land-use costs accounted for 4.3% and 5.4%, respectively, while non-profit farms incurred 3.9% and 4.3%, respectively (Fig. 4). Moreover, the estimated depreciation cost varied in a range of USD 321.69 to 461.18 ha^{-1} for both farms (Table 4). In a summation, the total cost of profit farms was less than the non-profit farms.

3.3. Financial gain/loss of profit and non-profit farms

By multiplying the total amount of production by the current market prices, the total return was computed. On average, productivity was found to be 27,070 kg ha^{-1} and 17,282 kg ha^{-1} for profitable pangasius and tilapia farms, respectively (Table 4). The average monetary value of total return was calculated as USD 32529.54 ha^{-1} and USD 24019.34 ha^{-1} of pangasius and tilapia profit farms, respectively. However, the maximum gross return and net return were reported in pangasius over tilapia farming. It might be due to higher production, although the average market price of pangasius is lower than tilapia. On the other side, non-profit farms have negative net returns because of their higher production cost compared to returns. Due to a considerably higher per unit total cost, tilapia farmers have suffered a one-and-a-half times greater loss than pangasius producers. Considering the cost-benefit analysis, the estimated benefit-cost ratio of pangasius and tilapia was near each other: 1.26 and 1.23, respectively, for profit farms. The findings are consistent with the study of Mukta et al. (2019), Ferdoushi et al. (2019), and Aktar et al. (2018). BCR was less than one for non-profit farms, estimated as 0.82 to 0.75 for pangasius and tilapia, respectively. These findings were consistent with Phiri and Yuan (2018) found that 15% of tilapia farmers did not make a profit in Malawi with a BCR range of 0.91 to 0.99. Nonetheless, pangasius and tilapia farms had average BCRs of 1.14 and 1.10, respectively, which implies that overall pangasius farming is relatively more profitable.

3.4. Strategies to improve the profitability of non-profit farms

Some fish farmers are incurring heavy losses due to the market price of fish remaining stagnant amid spiraling production costs. Thus, many orthodox fish farmers are even thinking of stopping fish production and changing business as they could not even able to meet the production cost, they spent on fish production by selling their produce in the market. In such a situation, we have to take measures to avert this condition to minimize their losses. Therefore, some measures are given below for non-profit farms to overcome their losses.

3.4.1. Input use nature of profit and non-profit farms

The efficient utilization of inputs is critical for achieving maximum output in the production process. As a result, a scientific understanding of input usage is imperative for optimizing output. This section discusses how profit and non-profit farms utilize inputs and what a non-profit farm may learn from a profit farm. To overcome losses, the farmer needs to adjust their inputs in the production process.

Input optimization and cost minimization for each farm would require to maximize productivity and profitability. Farmers have to identify inputs that significantly influence production costs in pangasius and tilapia production for non-profit farms. The *t*-test results are shown in Table 5 to understand better the differences in input use between profit and non-profit farms. Non-profit pangasius farms stocked 7133 ha^{-1} more fingerlings and 5082 ha^{-1} more tilapia than profit farms, which is statistically significant at a 1% level. It implies that non-profit farms are stocking more for better productivity but overstocking decreases productivity. Therefore, scientific knowledge of stocking density is very much essential to be profitable. Moniruzzaman et al. (2015) discovered that the growth of lower stocking density fingerlings is significantly higher than that of higher stocking density fingerlings in terms of final body length and weight, weight increase, and percent weight gain. The non-profit farms are using significantly more feed than the profit farms in both pangasius and tilapia. Although feeds are the primary input of aquaculture, a sufficient amount of feed is needed to get better productivity. However, overuse of feed results in production losses because the surplus feed settles in the pond's bottom or floats on the water, resulting in unclean pond water. Besides, that may have resulted in a foul smell from the pond water and lessened fish growth. In the case of pangasius, fertilizer use and miscellaneous cost were significantly more for the non-profit farms, creating a loss situation for the farms because this input does not directly influence productivity. Non-profit farms, on the other hand, had a labor use intensity that was insignificantly lower than profit farms. Despite its insignificant findings, causation must be considered in order to promote optimal labor use and increase per man-day labor productivity.

On the contrary, water exchange costs and miscellaneous costs were more in tilapia farms that were operating in a loss position. To attain breakeven yield, non-profit farms should reduce these input costs. Profitable farms were spent less on the input than non-profit farms, but in the end, profitable farmers are the gainer. Hence, there need to be a proper input costs management system for non-profit farm to outfight that problem.

3.4.2. Productivity needs to be increased to reach breakeven yield for non-profit farms

Every farmer desire to earn profit from their yield but not all of them succeed in doing so. To gain profit, a farmer needs to increase output while reducing the cost of inputs. Besides, they need to be well aware of other management practices that help lower the expenses. It was found that the average productivity of the profitable pangasius fish farms was 27,070 kg ha^{-1}. On the contrary, the average productivity of the non-profit farms was 21,170 kg ha^{-1}, which was 5900 kg ha^{-1} lower than that of the profitable farms (Table 6). If the non-profit pangasius farms increased their productivity level up to 25,672 kg ha^{-1}, they would reach their breakeven point that would not make any profit or any loss either. Now, if the non-profit farms can bring their total cost down to be likely of the profit farms (since the profit farms could generate profit at that same cost), then the new breakeven point for the non-profit pangasius farms stands at 21378 kg ha^{-1} (Table 6). It means that after lowering the total cost, the non-profit farms would have to increase their productivity by 208 kg ha^{-1}. However, the new breakeven yield would allow farmers to reach the breakeven point by producing 4294 kg ha^{-1} less amount of fish.

On the other hand, the average productivity of a profitable tilapia fish farm was17282 kg ha^{-1} whereas, the average productivity of a non-profitable farm was 16,680 kg ha^{-1}. If the non-profitable farms want to reach the breakeven point, they have to increase their productivity to 24,160 kg ha^{-1}, which was higher than their current productivity by 7480 kg ha^{-1}. But if the non-profitable farms managed to reduce their total cost to USD 19742.55 ha^{-1} and the breakeven price could be set at USD 1.65 kg^{-1}, then they can reach the breakeven point by merely producing at 14498 kg ha^{-1}. Hence, considering tilapia production, if the farmers manage to reduce total input cost, they can earn a profit because their average yield was higher than the new breakeven yield.

As a result, farmers might better combine their inputs and enhance overall management methods to lower per-unit production costs. A significant share of fish farms in Bangladesh is continuing to operate despite a lack of capital (Dey et al., 2010b). Furthermore, the bank demands substantial collateral, such as land or long-term assets, which makes loans available to small-scale farmers challenging (Alam and Guttormsen, 2019). Low capital and credit availability make it difficult for fish farmers to purchase necessary inputs such as feed, fingerlings, and labor. Hence, if farmers are unable to effectively control these production inputs, there should be an innate departure from the business via market mechanisms, resulting in revenue loss. The government can provide training to these farmers so that they can get the information and skills they need to manage their farms profitably.

3.5. Economies of scale of pangasius and tilapia farming

Theoretically, when the productivity is low, the per-unit cost of production is high and vice versa. Thus, when we say productivity falls, we say that costs rise due to the inverse relationship between cost and quantity. Furthermore, when a farm's output level rises, it enters a cost advantage scenario, as defined by the theory of economies of scale. However, the farms might be experienced diseconomies of scale with the increasing output after a certain level. Hence, farmers must select the cost-minimizing combination of inputs for their chosen output level to maximize profit. For that reason, the measurement of the cost of production at the farm level can improve farmers' decisions by providing a means for assessing management strategies to achieve greater efficiency and a high profit. The result revealed that pangasius and tilapia production costs were sensitive to changes in yields (Fig. 5).

Fig. 5 showed an inverse relationship with costs declining as yields increased to approximately 52,000 kg ha^{-1} of pangasius production. Up to the point (52,000 kg ha^{-1}), farms enjoy economies of scale by increasing the output level but, beyond 52,000 kg ha^{-1} of production, farmers fell into diseconomies of scale, which means an increase in output beyond 52,000 kg ha^{-1} leads to a rise in the average per-unit cost of production. In the case of tilapia, up to approximately 70,000 kg ha^{-1} of production, farmers could diminish their per unit of production cost. Above this level, any increase in output leads to a rise in average per-unit costs. Hossain et al. (2022b) also unearthed the optimal level of output at which carp fish farmers may benefit from the cost advantage, claiming that carp polyculture farming can benefit from economies of scale up to 8922 kg ha^{-1}. Pangasius and tilapia farming, on the other hand, have substantially higher productivity, allowing them to take advantage of the economies of scale theory.

3.6. Sensitivity analysis

The breakeven yield was inversely related to pangasius and tilapia fish prices. Only profit farms were subjected to the sensitivity analysis in order to determine how their profit was affected by the price of fish and feed. We skipped over non-profit farms because they are already in a financial bind, and how they might overcome this is detailed in the preceding section. Table 7 showed that when the fish price surged by 10%, BEY declined from its' usual condition of 21,973.43 kg ha^{-1} to 19,975.85 kg ha^{-1} and 13,992.89 kg ha^{-1} to 12,720.81 kg ha^{-1} for pangasius and tilapia, respectively. Conversely, when fish price decreased by 10% from its business as usual scenario, BEY increased to 24,414.92 kg ha^{-1} for pangasius and 15,547.65 kg ha^{-1} for tilapia farming. Hence, it was found that the BEY decreased by 9–16% for a 10–20% increase in the fish price from the current market price. Kumar

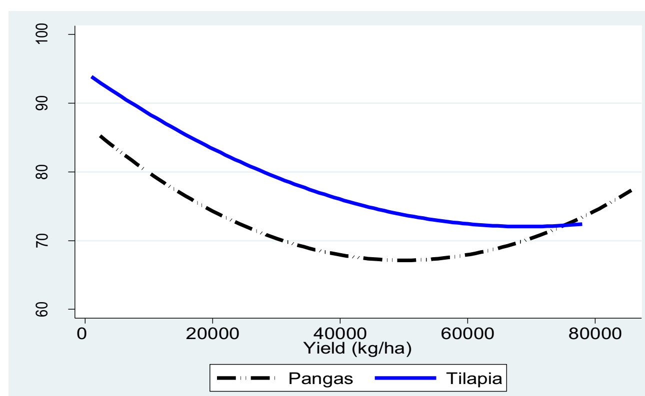

Fig. 5. Effect of various yields on BEP to cover the per-unit cost of pangasius and tilapia production.

Table 6
Output combination to reach BEY for pangasius and tilapia farming.

Particulars	Pangasius farm		Tilapia farm	
	Profit	Non-profit	Profit	Non-profit
Total cost (USD ha^{-1})	26,415.37	30,750.13	19,742.55	33,927.51
Average yield (kg ha^{-1})	27,070	21,170	17,282	16,680
Average price (USD kg^{-1})	1.22	1.24	1.45	1.54
Breakeven yield (BEY)	21,973	25,672	13,993	24,160
Breakeven price (BEP)	1.00	1.58	1.19	1.65
New BEY for non-profit farm $= \frac{\text{Total cost of profit farm}}{\text{Average price of non}-\text{profit farm}}$		21,378		14,498

Table 7
BEY required to cover total costs at various levels of pangasius and tilapia fish price.

Scenario	Pangasius		Tilapia	
	Price (USD kg^{-1})	BEY (kg ha^{-1})	Price (USD kg^{-1}.)	BEY (kg ha^{-1})
Business as usual	1.22	21,973.43	1.45	13,992.89
Fish price reduced by 20%	0.97	27,466.79	1.16	17,491.11
Fish prices reduced by 10%	1.10	24,414.92	1.30	15,547.65
Fish price increased by 10%	1.35	19,975.85	1.59	12,720.81
Fish price increased by 20%	1.48	18,311.19	1.74	11,660.74

et al. (2018) found that breakeven yields were inversely related to catfish prices and they decreased by 8–11% for every \$0.22 kg^{-1} increase in catfish price. According to Hossain et al. (2022b), for every USD 0.24 kg^{-1} change in the carp fish price, the break-even yield dropped by 14 to 25%. Consequently, if the market price of fish climbed, fish farmers needed a lower amount of fish to cover the overall cost and to earn a profit.

A sensitivity analysis was performed to make a justifiable statement about pangasius and tilapia farming's profitability. Farmers are highly demotivated to cultivate pangasius and tilapia due to low market prices and high production costs (Mukta et al., 2019). Hence, to make pangasius and tilapia farming sustainable and feasible, the sensitivity analysis was performed to demonstrate how the farmer's financial benefit varied with the alteration of feed and output price. The assessment was conducted on five different scenarios relative to business as usual (Table 8). Keeping all other criteria constant, if the feed cost could be brought down by 10%, then BCR becomes 1.33, which will allow farmers to gain a profit of about USD 0.30 per kg of fish, which was previously only USD 0.23. Besides, profitable pangasius farms could bring down the variable cost per kg of fish from USD 0.98 to USD 0.90. On the other hand, BCR became 1.31 for profitable tilapia farms, and the benefit from selling per kg of fish would rise from USD 0.25 to USD 0.33. In the same scenario, the variable cost per kg of fish also was lowered to USD 1.07 from USD 1.19 for tilapia fish farming. Similarly, if the output price was raised by merely 10% while keeping other factors constant, BCR becomes 1.35 for pangasius farms whereas BCR was estimated as 1.34 for tilapia farms, NPM increased from 18 to 25%, but VCK remained the same. In such circumstances, the profit from selling per kg of fish was raised to USD 0.34 for pangasius farms and USD 0.39 for tilapia farms, surpassing the 10% reduction in feed price. However, we can comprehend that augmenting the fish price is much more profitable to the farmers than a feed price reduction. The findings show that a decrease in feed price or an increase in output price may be an effective policy for sustainable pangasius and tilapia farming. Based on the findings, it can be stated that a strategy involving a single or a combination of initiatives, such as lowering feed prices while preserving feed quality and raising output prices, could be beneficial in ensuring the long-term viability of pangasius and tilapia farming in Bangladesh. To improve feed quality, it is suggested that government should play an active role to inspect the quality of available commercial feed in the market. Local nutritive feeds and feed materials should also be widely available in markets to reduce the dependency on commercial pelleted feed and subsequently dwindle its market price. Furthermore, a well-structured fish pricing strategy based on consumer demand and purchasing power should be devised in both producing and consuming regions. The finding of this study is in line with Mukta et al. (2019) and Kumar et al. (2018), who observed that the financial benefit of farms was sensitive to changes in feed and output price and exhibited an inverse relationship with cost and benefit-cost analysis.

3.7. Monte-Carlo simulation results of profit under feed price, yield, and market risks

The simulation result showed that the minimum range of profit from the pangasius farm was found to be USD −39,209.73 ha^{-1} implies a possibility of a pangasius producer suffering a significant loss at that value (Table 9), whereas it was found USD −45,915.38 ha^{-1} for tilapia farm. But there was also the possibility of making a higher profit since the maximum range of earnings from pangasius farming was USD 50503.62 ha^{-1}. However, the most likely amount of profit from one-hectare pangasius production was USD 4875.43 ha^{-1}. On the other hand, there was a possibility of making a loss in tilapia farming because its minimum value was much lower than the positive value. The results revealed that the most likely profit of the tilapia farm was USD 2099.14 ha^{-1}. The potential risk of gaining profit was higher for pangasius compared to tilapia. Furthermore, the probability of loss for pangasius and tilapia was 39% and 33%, respectively. Pangasius fish farming can be characterized as more capital intensive, high mortality rate, and lower market price. Besides, pangasius fish farmers follow a non-optimal fingerling stocking density, which might lead to high mortality and stagnant growth rates, eventually, increasing the probability of loss (Khan et al., 2018). The Monte Carlo simulation confirmed the previous results of the overall farm's profit and demonstrated that farms that got more output prices irrespective of productivity are more resilient in adverse market scenarios. However, farms' economic performance varied mainly regarding their output price, production capacity, and feed price. Therefore, attention to the fish and feed price is crucial for commercial farms' economic feasibility alongside productivity.

Table 9
Results of the profits from the Monte-Carlo simulation (USD ha^{-1}).

Parameters	Pangasius	Tilapia
Mean	4875.42	2099.15
Std. deviation	14,356.75	12,581.03
Maximum	50,503.62	52,026.26
Minimum	-39,209.73	-45,915.38
Coefficient of variation (CV)	294.47	213.90
Probability of loss (%)	39	33

Table 8
Sensitivity analysis of feed and output price changes and their effects on financial benefit of profit farms.

Scenario	Pangasius						Tilapia					
	BCR	GPM	NPM	BEP	VCK	BKF	BCR	GPM	NPM	BEP	VCK	BKF
Business as usual	1.26	19.39	18.71	1.00	0.99	0.23	1.23	18.76	18.10	1.19	1.18	0.26
Feed price reduced by 10%	1.33	25.64	25.02	0.90	0.89	0.30	1.31	24.23	23.63	1.07	1.07	0.33
Feed price reduced by 20%	1.45	31.87	31.25	0.83	0.82	0.38	1.42	30.05	29.45	0.99	0.98	0.41
Output price increased by 10%	1.35	26.74	26.18	1.00	0.99	0.35	1.34	25.82	25.28	1.19	1.18	0.39
Feed price reduced by 5% and output price increased by 5%	1.34	26.21	25.63	0.94	0.93	0.32	1.32	25.06	24.49	1.11	1.11	0.36
Feed price reduced by 10% and output price increased by 10%	1.47	32.40	31.83	0.90	0.89	0.42	1.44	31.11	30.57	1.07	1.07	0.47

Note: BCR: Benefit-Cost Ratio; GMP: Gross Profit Margin; NPM: Net Profit Margin; BEP: Breakeven price; VCK: Variable cost per kg of fish production at USD; BKF: Benefit from per kg fish at USD.

4. Concluding remarks and policy recommendations

In order to extend pangasius and tilapia farming across the country and maintain its long-term viability, farmers must be made aware of the economic implications of input use and profit-making processes. With the right combination of inputs, aquaculture production may be turned into more profitable, and non-profit farms can recover their losses. Therefore, this study tried to investigate the profit-making mechanism of aquaculture farms, the variation of inputs used by profit and non-profit farms, and ways to improve financial performance for non-profit farms. The findings of the study represented that pangasius fish farming was more profitable than tilapia farming due to higher productivity, while some farms were non-profitable. The non-profit farms use some of the production inputs, i.e., fingerlings, feed, labor, etc., incautiously. In the case of non-profit farms, it was estimated that if farmers manage to attain breakeven prices and productivity along with the optimum combination of inputs, they can convert themselves into profit farms. The optimal amount of production for pangasius and tilapia to function within the bounds of economies of scale was also determined in this study. Regarding sensitivity analysis, farmers' economic performance was vulnerable to the alteration of feed prices and fish prices. However, productivity, fish price, and feed price were the major risk indicators for pangasius and tilapia farming. The potential risk of gaining profit was higher for pangasius compared to tilapia farming.

Based on the above consideration, the study suggests proper utilization of fingerling, feed, and labor should be ensured to reduce cost and, ultimately, the loss of non-profit pangasius and tilapia farms. To make efficient use of these inputs, proper extension support from the government, NGOs, and feed companies should be taken place. The study applied sensitivity analysis for feed price and output price of pangasius and tilapia farming. Therefore, the research suggests reducing the feed price by enhancing the feed quality and increasing the output price to a reasonable limit would make pangasius and tilapia farming a more profitable venture in Bangladesh. To ensure feed quality, regional feed research institutes should be established, and all feed companies should be brought under the surveillance of this institute. In this regard, continuous monitoring of fish feed quality by the Department of Fisheries in partnership with the Bangladesh Fisheries Research Institute and aquaculture and fisheries departments of various agricultural universities would most likely be a realistic and cost-effective approach. Besides, the uninterrupted movement of fish from production areas to every corner of the country should be enhanced through smooth transportation facilities to ensure the rational fish price.

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CRediT authorship contribution statement

Priyanka Saha: Conceptualization, Data curation, Methodology, Formal analysis, Writing – original draft. **Md. Emran Hossain:** Conceptualization, Data curation, Methodology, Formal analysis, Writing – original draft. **Md. Masudul Haque Prodhan:** Methodology, Formal analysis, Writing – original draft. **Md. Takibur Rahman:** Investigation, Visualization, Writing – original draft. **Max Nielsen:** Project administration, Funding acquisition, Writing – review & editing. **Md. Akhtaruzzaman Khan:** Project administration, Funding acquisition, Writing – review & editing, Supervision.

Declaration of Competing Interest

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.

Data availability

Data will be made available on request.

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