

Impact of Farmers' Training on Technology Adoption, Profitability and Farm Income in Tilapia Farming

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Abstract

Farmers' training plays a pivotal role in the sustainable development of aquaculture by promoting the adoption of improved technologies and the efficient use of production inputs. In Bangladesh, many institutions provide training to fish farmers to enhance their technical knowledge and management skills. This study investigates whether such training facilitates technology adoption and improves profitability and farm income. Specifically, it examines the effects of farmers' training on the adoption of semi-intensive (improved) tilapia farming technology and on the economic performance of fish farms in the Sylhet district of Bangladesh. Primary data were collected from 99 tilapia farmers across three upazilas: Sylhet Sadar, South Surma, and Golapganj, covering the period from July 2015 to June 2016. A Logit model was used to assess the influence of formal education, training, and access to institutional credit on technology adoption. Farm profitability was estimated using net returns, while farm income was measured as returns to land, family labor, and management. The results indicate that both training and access to formal credit have a statistically significant and positive influence on the adoption of improved technology. Trained farmers achieved 78% higher yields and 137% higher profitability than their non-trained counterparts. The per-hectare profit of trained farmers (Tk. 296,674) was more than twice that of non-trained farmers (Tk. 125,191). Similarly, the average annual income of trained farmers (Tk. 188,068) exceeded that of non-trained farmers (Tk. 91,682) by 105%. These results underscore the importance of continued investment in well-designed, need-based farmer training programs to accelerate technology adoption, increase production, and farmers' income in Bangladesh.

Key Words: Farmers, Training, Technology, Adoption, Profitability, Farm, Income, Tilapia.

1. Introduction

Farmers' training is fundamental to the sustainable development of aquaculture. It builds technical knowledge and practical skills essential for improving productivity, profitability, and environmental performance (Menezes et al., 2022). Well-structured training enables farmers to acquire critical competencies in pond preparation, water quality management, feed formulation, and disease prevention, directly influencing fish growth and yield (Murshed-e-Jahan, Beveridge, & Brooks, 2008). Moreover, trained farmers tend to adopt improved technologies, use inputs

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more efficiently, employ bio-secure management, and adopt environmentally responsible practices that reduce production costs while minimizing ecological impacts (Murshed-e-Jahan, Ahmed, & Belton, 2010).

In recent years, experiential learning models such as aquaculture field schools have proven highly effective in improving farm productivity and household income (Widowati et al., 2021). Moreover, decentralized and participatory extension systems have strengthened farmers' problem-solving capacity and resilience to climate and market shocks (Dompheh, Ferdous, & Hossain, 2024). Evidence from institutional programs, particularly those led by the WorldFish Center, demonstrates that sustained technical support and capacity building substantially increase adoption of improved aquaculture technologies, thereby contributing to enhanced productivity, higher household income, and food security (WorldFish Center, 2003). The Department of Fisheries (DoF) plays a central role in farmer training through its Fisheries Training and Extension Centers. Complementary initiatives are also implemented by the Bangladesh Fisheries Research Institute (BFRI), agricultural universities, non-governmental organizations (NGOs), and development partners.

In Bangladesh, tilapia farming has emerged as one of the fastest-growing sectors in aquaculture, driven by favorable climatic conditions, technological advancements, and rising market demand. According to the FAO (2022) report, "The State of World Fisheries and Aquaculture 2022," Bangladesh ranked 4th in tilapia production globally and 3rd in Asia. The total production of tilapia has increased from approximately 10,000 metric tons in 2000/01 to 439,678 metric tons in 2023/24 (DoF, 2024). Despite extensive training investments, empirical evidence on how training affects technology adoption, profitability, and income among tilapia farmers remains limited. Assessing these linkages is critical for guiding future extension strategies and optimizing resource allocation in aquaculture development.

This study investigates the impact of farmers' training on technology adoption, profitability, and farm income in tilapia farming in the Sylhet district of Bangladesh. The specific objectives of the study are to: (i) identify factors (especially the role of farmers' training) influencing the adoption of improved tilapia farming technology; (ii) compare input use, yield, and profitability between trained and non-trained farmers; and (iii) estimate differences in annual farm income across farmer groups. The findings from this study are expected to inform evidence-based policy and extension strategies that enhance sustainable aquaculture growth and rural livelihoods in Bangladesh and other developing countries.

2. Research Methodology

2.1 Theoretical Framework of the Study

Understanding how farmers' training influences technology adoption, profitability, and farm income requires a multidisciplinary perspective that draws on theories from behavioral science, economics, and innovation diffusion. Three major frameworks are available, namely, Human Capital Theory, Rogers' Diffusion of Innovations Theory, and the Technology Acceptance Model

(TAM). These models jointly explain how training affects farmers' knowledge, perceptions, and decisions regarding the adoption of improved aquaculture technologies.

Human Capital Theory: According to the Human Capital Theory, education and training constitute investments that enhance individuals' knowledge, skills, and productivity, leading to higher economic returns (Becker, 1964). In aquaculture, training enhances farmers' technical competence in areas such as pond preparation, feed management, and water quality control, thereby increasing production efficiency and profitability. Enhanced human capital also strengthens farmers' ability to adopt new technologies and manage risks. Studies in agriculture and aquaculture have demonstrated that trained farmers achieve higher yields and better financial performance than untrained farmers, primarily due to improved management practices and more efficient resource utilization (Asfaw & Admassie, 2004; Ragasa et al., 2022).

Diffusion of Innovations Theory: Rogers' (2003) Diffusion of Innovations theory offers a sociological explanation for the spread of new technologies through communication and social systems. Adoption depends on five key innovation attributes—relative advantage, compatibility, complexity, trialability, and observability. Training enhances these attributes by demonstrating the advantages of new practices, reducing their perceived complexity, and providing observable results. Through farmer-to-farmer interaction, trained individuals serve as opinion leaders, accelerating the diffusion of information within communities. In aquaculture, field-based training and participatory learning, such as Aquaculture Field Schools, have been demonstrated to facilitate collective learning and enhance technology adoption (Widowati et al., 2021).

Technology Acceptance Model (TAM): The Technology Acceptance Model (Davis, 1989) complements diffusion theory by focusing on individual behavioral intentions toward technology use. TAM posits that adoption is influenced by two perceptions: perceived usefulness (the belief that technology improves performance) and perceived ease of use (the belief that it is simple to operate). Training directly affects both perceptions by providing hands-on experience, simplifying complex tasks, and demonstrating tangible economic benefits such as higher yields or reduced costs. As knowledge and confidence grow, farmers' perceived usefulness and ease of use increase, reinforcing their willingness to adopt and continue using improved technologies.

Integrative Conceptual Framework: By integrating these theories, this study conceptualizes farmers' training as a catalyst that builds human capital and shapes behavioral intentions toward the adoption of technology. Improved knowledge and technical capacity reduce uncertainty, increase the perceived benefits of innovation, and promote the adoption of improved tilapia-farming technologies. Adoption, in turn, enhances production efficiency and profitability, which subsequently raises farm income. The framework also acknowledges mediating and moderating factors, such as access to credit, market conditions, and institutional support, that can strengthen or weaken these causal pathways.

Figure 1 shows the conceptual framework of our study. We argue that providing knowledge and skills through farmers' training and augmenting financial constraints through institutional credit contribute to the adoption of improved fish production technology, higher yields, increased

profits, and higher incomes. Lack of financial capital was identified by producers as a major constraint to the commercialization of aquaculture in Bangladesh (Murshed-e-Jahan et al., 2015). The productivity and input use of credit-constrained aquaculture farmers is significantly lower than that of unconstrained farmers (Mitra et al., 2019).

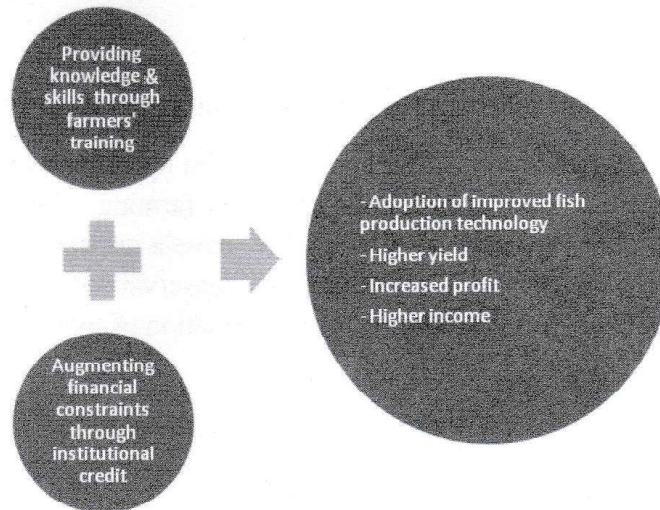


Figure 1. Conceptual Framework of the Study.

2.2 Data Sources

We conducted a survey among 99 tilapia farmers from three Upazilas (Sylhet Sadar, South Surma, and Golapganj) in Sylhet District from July to December 2015. We have analyzed the farm survey data in this study.

2.3 Analytical Framework

2.3.1 Adoption of Semi-intensive Production Technology

We have estimated a binary logit model (as in Equation 1) to examine the influence of training and access to financial resources (i.e., a loan) on the probability of adopting semi-intensive (improved) tilapia production technology. Formally, the model is specified as:

$$\text{Logit} (P_i) = \ln \left(\frac{P_i}{1-P_i} \right) = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \dots + \beta_k X_{ki} \dots \dots (1)$$

where P_i denotes the probability that the farmer i is going to adopt the semi-intensive (improved) tilapia farming technology, β_0 is the intercept, β_j are the coefficients, and X_j represent explanatory variables. The explanatory variables comprised four variables: age,

the farmer's education level, training, and a loan from institutional sources. Thus, our empirical logit regression model was in the form of Equation 2.

$$Adopt_i = \beta_0 + \beta_1 AGE_i + \beta_2 EDU_i + \beta_3 TRAIN_i + \beta_4 LOAN_i + \mu_{ij} \dots \dots (2)$$

Where,

$Adopt_i$ = Farmer i has adopted semi-intensive (improved) technology or not (1 = Yes, 0 = No)

AGE is the age of the farm operator (years). The age of the farm operator is expected to have a positive or negative impact on technology adoption in tilapia farming. The older farmers are likely to have had more farming experience and, therefore, have a greater interest in adopting new technologies. However, they are also likely to be more conservative and, thus, less willing to adopt new practices, which may result in a lower level of adoption of semi-intensive technologies for tilapia production.

EDU refers to the education level of farm operators and is expected to have a positive impact on the level of technology adoption. That is, we expect that greater levels of formal education among farm operators will be positively associated with the adoption of technology. EDU_i = Farmer i received secondary education or not (1 =Yes, 0 =No)

TRAIN is the variable of whether the farmer received any training for fish production. We expected that training would have a positive effect on technology adoption. In other words, farmers with training in fish production will adopt semi-intensive (improved) tilapia farming technology. $TRAIN_i$ = Farmer i was trained or not (1 =Yes, 0 =No)

LOAN is the variable indicating whether the farmer obtained credit from institutional sources. We assume that access to financial capital (in the form of a loan) has a positive effect on technology adoption in tilapia farming. $LOAN_i$ = Farmer i has obtained institutional loan or not (1 = Yes, 0 = No)

The probability function for the binary outcome is expressed as:

$$P_i = \frac{\exp(\beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \dots + \beta_k X_{ki})}{1 + \exp(\beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \dots + \beta_k X_{ki})} \dots \dots \dots (3)$$

To facilitate interpretation, marginal effects were computed for each explanatory variable, indicating the change in the probability of adopting semi-intensive tilapia farming technology resulting from a unit change in the predictor.

2.3.2 Profitability in Tilapia Farming

To quantify the profitability of tilapia farming, we have identified all expense items and income sources associated with tilapia production. We have quantified the input use level and associated costs of inputs used by trained and non-trained fish farmers. We have also gathered data on fish

production and prices received by the farmers. For a comprehensive understanding, we estimated the amount of total revenue (also known as gross revenue), total costs, and net returns. Also, we calculated break-even prices and yields.

Total revenue from tilapia farming refers to the total earnings from selling tilapia. It is obtained by multiplying the total output (quantity of fish produced) by the price of the output (fish price). We have used Equation (4) for calculating the total revenue.

$$\text{Total Revenue} = (\text{Total Output}) \times (\text{Price}) \quad \dots (4)$$

The total cost is the sum of all costs involved in tilapia production. Equation (5) can be used to calculate the total cost.

$$\text{Total Costs} = (\text{Total Variable Costs}) + (\text{Total Fixed Costs}) \quad \dots (5)$$

For a tilapia farm, there are two types of costs: variable costs and fixed costs. Variable costs are expenses that fluctuate in proportion to the quantity of fish produced. In our case, these are costs for fingerlings, cow dung, lime, mustard oilcake, rice bran, Urea, TSP, and labor. On the other hand, fixed costs are expenses that remain constant regardless of the level of production. It includes the cost of the rental value of the ponds used to produce tilapia.

Net return is the amount that a farm receives after paying for all inputs. Net returns indicate the profitability of a tilapia farm. It is calculated by deducting the total costs from the total revenue. For family-owned inputs, such as family labor and management, we have used imputed values based on the market price. Equation (6) is used to calculate Net Returns.

$$\text{Net Returns} = (\text{Total Revenue}) - (\text{Total Costs}) \quad \dots (6)$$

We have also computed two other useful information relevant for farmers: break-even price and break-even yield. Break-even price (BEP) is the price that a farm must receive to cover all the costs. It is also known as the per-unit cost of production. Using Equation (7), we calculated the BEP for both trained and non-trained tilapia farmers.

$$\text{BEP} = \text{Cost of Production (in Tk/Kg)} = (\text{Total Costs in Tk}) / (\text{Total Production in Kg}) \quad \dots (7)$$

Break-even yield (BEY) is the yield that a farm must receive to cover all costs when the farm sells the output at the existing market price. Equation (8) is used to calculate the BEY for trained and non-trained tilapia farmers.

$$\text{BEY} = (\text{Total Costs in Tk}) / (\text{Price of tilapia in Tk/Kg}) \quad \dots (8)$$

2.3.3 Income from Tilapia Farming

We have calculated farm income by determining returns to land, family labor, and management. In Bangladesh, there is no established market value for family labor and management in fish farms, nor for the use of one's own resources (land used in fish farming). Researchers use the wage rate of hired labor to impute the value of family labor and the time spent managing the fish

farm. The rental value of the land is used to calculate the cost of land. Family members may be able to share their available spare time to feed the fish and manage the fish farm, but not be gainfully employed in any outside jobs. Similarly, it may be possible to use your pond and ditch for fish production, but they cannot be rented to another person without compromising other uses, such as bathing, washing, and household water needs. Therefore, we use a better indicator to understand income from fish farming. It is referred to as "Returns to land, family labor, and management," which is calculated using Equation (9).

Returns to land, family labour, and management = Total Revenue – Total Costs (excluding the costs of family labour, management, and land) ... (9)

3. Results and Discussion

3.1 Basic Characteristics of the Sample Farms

Table 1 shows the basic characteristics of the sample farms. Approximately 59 percent of the sample farmers adopted semi-intensive (improved) production technology, while 41 percent used extensive technology. Average pond area per farm for extensive farmers and semi-intensive farmers was 58.1 decimals and 60.4 decimals, respectively. Approximately 59 percent of the tilapia pond area was cultivated using a semi-intensive method, and 41 percent of the pond area was cultivated using an extensive method.

Extensive aquaculture is a lightly stocked system where water throughput is not boosted, and feed or fertilizer inputs are not applied (Gomiero et al., 1997). Fish production depends on natural food sources within the culture unit (Edwards & Demaine, 1997). An extensive system in the empirical literature has been linked to feeding or fertilizing functions, but in limited quantities (Hari et al., 2006; Wahab et al., 2003; Dasgupta et al., 2008). Semi-intensive (improved) aquaculture systems can be defined as farms where feeding is carried out at least twice a week and fertilization is done once a week (Nilsson & Wetengere, 1994). The intensity of the system is correlated with the level of feed or fertilizers introduced into the system, as well as the levels of seed, labor, capital, and management (Edwards & Demaine, 1997).

There was not much difference in the formal educational attainment of the two groups of farmers. However, a higher percentage (19%) of non-trained farmers had secondary education, compared to trained farmers (11%). The average age of the sample farmers was 48 years. Although there was little difference in the age of trained and non-trained farmers, the average age of trained farmers was slightly higher. Almost all trained farmers (98%) adopted semi-intensive technology, whereas only 26% of non-trained farmers adopted semi-intensive technologies. Most (74%) of the non-trained farmers used extensive technology for tilapia production. More than half (54%) of the trained farmers received a loan from institutional sources, but only 26% of non-trained farmers took a loan from any institutional source.

Table 1. Basic Information about Tilapia Farmers.

Inputs	Non-trained Farmers	Trained Farmers	All
Number of farmers	53	46	99
Pond area per farm (Decimals)	58.8	60.3	59.5
Age (years)	46.4	49.5	47.8
Education level			
Primary	43 (81.1)	41 (89.1)	84 (84.8)
Secondary	10 (18.9)	5 (10.9)	15 (15.2)
Farms that received institutional loans	14 (26.4)	25 (54.3)	39 (39.4)
Tilapia production technology			
Extensive technology	39 (73.6)	1 (2.2)	40 (40.4)
Semi-intensive technology	14 (26.4)	45 (97.8)	59 (59.6)

Note: Figures in parentheses indicate the percentage of the total farmers in that category.

Source: Author's calculation.

3.2 Factors Influencing the Adoption of Improved Production Technology

As mentioned earlier, to examine the influence of formal education, training, and access to financial resources (loans) on the probability of adopting semi-intensive (improved) production technology, a logit regression model was estimated (Equation 1). Table 2 presents the results of a logistic regression model estimating the factors influencing farmers' adoption of improved fish farming technology. The explanatory variables include participation in farmers' training, access to loans, age, and education level. The dependent variable is binary, indicating whether a farmer adopted the improved technology (1 = adopter, 0 = non-adopter).

The model exhibits high explanatory power, with a pseudo R^2 of 0.62, indicating that the included variables account for 62% of the variation in adoption behavior. The Chi-square statistic ($\chi^2 = 83.02$, $p < 0.01$) indicates that the overall model is statistically significant.

Among the explanatory variables, training and access to loans have positive and highly significant effects ($p < 0.01$) on adoption. The estimated coefficient for training (5.20) implies that trained farmers are substantially more likely to adopt improved fish farming technology. The corresponding odds ratio (181.77) indicates that trained farmers are approximately 182 times more likely to adopt compared to non-trained farmers, while holding other factors constant. The marginal effect (0.79) indicates that training increases the probability of adoption by approximately 79 percentage points. Similarly, farmers with access to credit have a coefficient of 3.089 (statistically significant at 1% level of significance) and an odds ratio of 21.95, indicating that they are approximately 22 times more likely to adopt improved technology than those without loans. The marginal effect (0.47) indicates a 47-percentage-point increase in the adoption probability due to loan access.

Age (coefficient = 0.01) and education (coefficient = -0.09) have no statistically significant effects on adoption, indicating that these factors do not meaningfully influence technology uptake in this sample. The constant term (-2.67) is marginally significant ($p = 0.08$), reflecting a low baseline probability of adoption in the absence of training and access to institutional credit.

Several studies have reported similar findings. Ragasa et al. (2022) reported that participants in the training cohort had significantly higher adoption rates of improved tilapia technologies (fingerling quality and feeding practices) than non-participants in Ghana. The authors concluded that training enhances technical skills, decision-making confidence, and exposure to new practices. Das et al. (2014) found that education and training played an important role in the adoption of improved aquaculture technologies in Tripura, India. Widowati et al. (2021) showed that the aquaculture field school resulted in the adoption of liquid compost technologies in shrimp and milkfish ponds of Central Java (Indonesia) farmers. In Kenya, attendance at extension training significantly increased the likelihood of technology uptake (odds of adoption) among the analyzed smallholder fish farmers (Obiero et al., 2019). In Bangladesh, spousal education, training, extension contacts, and off-farm income sources played an important role in the adoption of improved carp polyculture management practices (Rahman et al., 2023).

Table 2. Logit estimation for the impact of farmers' training, access to loans, farmers' age, and education level on the adoption of improved (semi-intensive) fish farming technology.

Variable description	Estimated coefficient	Standard Error	Odds ratio	Marginal Effect	P value
Constant	-2.667*	1.543	0.069		0.08
Age	0.011	0.031	1.011	0.002	0.72
Training (Yes=1, No =0)	5.203***	1.140	181.771	0.789	0.00
Loan (Yes=1, No =0)	3.089***	0.788	21.950	0.469	0.00
Secondary Education (Yes=1, No =0)	-0.085	0.984	0.918	-0.013	0.93
Chi ²		83.02			
Prob > Chi ²		0.00			
Pseudo R ²		0.62			

Note:***p<0.01, **p<0.05and*p<0.10; n = 99.

Source: Authors' estimate.

Our findings do not support Islam et al. (2024), who reported that the training received by farmers had non-significant relationships with farmers' adoption of modern aquaculture technologies in fish farming. The study added that adopting modern aquaculture technology was significantly and favorably correlated with education, fish farm size, annual income from fish farming, experience with fish farming, and knowledge of fish farming technologies (Islam et al., 2024). We want to argue that the critical factor to notice here is the knowledge of fish farming technology, which can be enhanced through training.

Table 3 presents the predicted probabilities of adopting improved tilapia farming technology under various combinations of farmers' participation in training and access to institutional loans. These probabilities are derived from the estimated logit model presented in Table 2. The results clearly demonstrate the strong, complementary effects of both training and credit access on farmers' likelihood of adopting improved technology. When farmers receive neither training nor loans, the predicted probability of adoption is very low (only 7.6%), indicating that few non-trained and credit-constrained farmers adopt semi-intensive tilapia farming.

When farmers receive training but lack access to loans, the probability of adoption increases sharply to 93.7%, indicating that training alone substantially enhances farmers' knowledge, skills, and confidence in adopting improved practices. Similarly, when farmers do not receive training but have access to loans, the probability increases to 64.5%, suggesting that financial support alone also encourages adoption, though to a lesser degree than training.

The highest probability of adoption (99.7%) occurs when farmers receive both training and institutional loans, underscoring the synergistic impact of combining technical capacity-building with financial support. This finding highlights that integrated interventions (i.e., linking farmers' training with accessible credit) are most effective for promoting widespread adoption of improved tilapia farming technologies.

Table 3. Predicted probability of adoption of improved tilapia farming technology with training and access to institutional loans.

Training	Loan	Predicted Probability of Adoption
No	No	7.6%
Yes	No	93.7%
No	Yes	64.5%
Yes	Yes	99.7%

Sources: Authors' calculation.

3.3 Costs of and Returns to Tilapia Production

Table 4 reports per-hectare input use level and yield in tilapia cultivation by trained and non-trained fish farmers. Trained farmers used more input than non-trained fish farmers. The average per-hectare yield of tilapia among the sample farms was 4,018 kg. The per-hectare average yield of trained farmers (5,225 kg) was 77.5% higher than that of non-trained farmers (2,944 kg). Input use level for all inputs was higher for trained farmers than for non-trained farmers. Trained farmers used 53,318 fingerlings (i.e., 18.3% more fingerlings) than non-trained farmers (45,056). On average, trained farmers used 3,373 kg of cow dung, 286 kg of lime, 881 kg of mustard oilcake, and 903 kg of rice bran per hectare. On the other hand, non-trained farmers used 1,498 kg of cow dung, 173 kg of lime, 334 kg of mustard oilcake, and 363 kg of rice bran per hectare. In terms of chemical fertilizer use per hectare, trained farmers applied 29.1 kg of Urea and 12.6 kg of TSP, which was significantly higher than the amount used by non-trained farmers (16.2 kg of Urea and 7.4 kg of TSP). A higher level of input use resulted in a higher yield in tilapia for farmers who received training. In other words, farmers' training benefited the country by increasing fish production.

Our results corroborate those of Widowati et al. (2021), who showed that the aquaculture field school resulted in higher stocking densities, more use of inputs (manure, feed, and fertilizer), and increased yield of shrimp and milkfish in Central Java (Indonesia).

Table 4. Per-hectare input use level and yield (kg) in tilapia fish farming among the sample farms in Sylhet, Bangladesh.

Inputs	Non-trained farmers	Trained farmers	All
Fingerlings (Number)	45,056	53,318	48,947
Labor (Person-days)	165	307	232
Cow dung (Kg)	1,497.71	3,372.73	2,380.74
Lime (Kg)	172.52	286.21	226.06
Mustard Oilcake (Kg)	333.89	881.21	591.65
Rice bran (Kg)	363.28	902.64	617.29
TSP (Kg)	7.42	12.56	9.84
Urea (Kg)	16.22	29.05	22.26
Yield (Kg)	2,944	5,225	4,018

Source: Author's calculation.

Per-hectare costs of and returns from tilapia cultivation by trained and non-trained farmers are reported in Table 5. The average net return (i.e., profit or income) from tilapia farming among the sample farms was Tk 205,951 per hectare. The net return from tilapia production for trained farmers (Tk 296,674/Ha) was 137% higher than the net returns obtained by non-trained farmers (Tk 125,191/Ha). The average gross return received by the trained farmers was Tk 500,226/Ha, compared to Tk 253,470/Ha by the non-trained farmers. The average Total Costs of tilapia farming were Tk 203,553/Ha for trained farmers, while they were Tk 128,279/Ha for non-trained farmers. The per-kilogram production cost (also known as the break-even price) for tilapia was 10.6% lower for trained farmers (Tk 38.96) than for non-trained farmers (Tk 43.57). The benefit-cost ratio (BCR) in tilapia farming was 2.46 for trained farmers and 1.98 for non-trained farmers. Break-Even yield was 2,126 kg/ha for trained farmers and 1,490 kg/ha for non-trained farmers. In other words, at the current market price, to cover production costs only, the minimum yield per hectare should be 2,126 kg for trained farmers and 1,490 kg for non-trained farmers.

Table 5. Per-hectare costs and returns from Tilapia farming among the sample farms in Sylhet, Bangladesh.

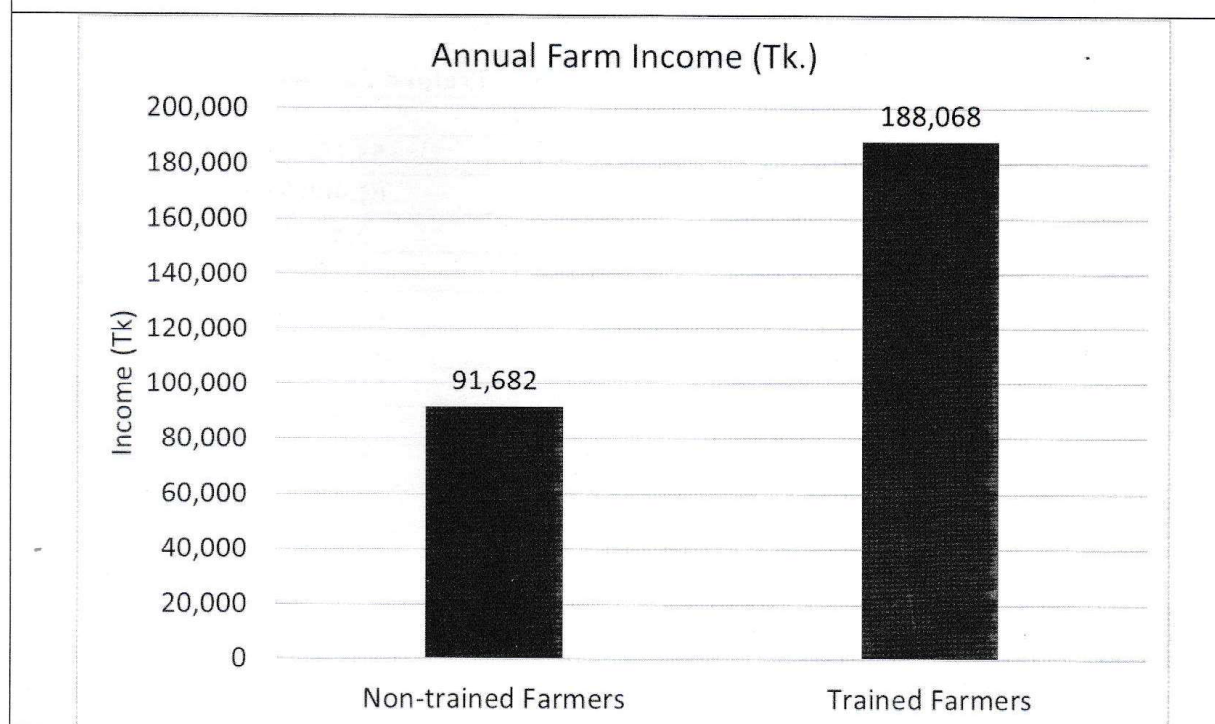
Description	Non-trained Farmers	Trained Farmers	All
COSTS			
Fingerlings (Tk.)	38,978.50	53,154.53	45,654.67
Labor (Tk.)	33,074.52	61,400.71	46,414.68
Cow dung (Tk.)	2,996.69	5,678.61	4,259.73
Lime (Tk.)	3,451.85	5,726.56	4,523.12
Mustard oilcake (Tk.)	10,021.09	26,447.47	17,757.06
Rice bran (Tk.)	7,268.73	18,060.43	12,351.06
TSP (Tk.)	163.23	276.52	216.58
Urea (Tk.)	292.10	523.09	400.88
Harvest cost (Tk.)	17,212.27	17,464.65	17,331.12
Rental value for land (Tk.)	14,820.00	14,820.00	14,820.00
Total Cost (Tk.)	128,278.98	203,552.57	163,728.93
RETURNS			
Yield (Kg)	2,944	5,225	4,018
Price (Tk./Kg)	86.09	95.74	92.00
Gross Return (Tk.)	253,470.18	500,226.49	369,679.57
Net Return (Tk.)	125,191.20	296,673.92	205,950.65
Returns to Land, Family Labour and Management (Tk.)	190,297.99	390,359.27	284,516.45
Break-Even Yield (Kg/Ha)	1,490	2,126	1,780
Break-Even Price (Tk/Kg)	43.57	38.96	40.75
Benefit-Cost Ratio (BCR)	1.98	2.46	2.26

Source: Authors' calculation.

3.4 Income from Tilapia Farming

Figure 2 illustrates the annual farm income of an average tilapia farm for the 2015/16 period. On average, the sample farmers had 59.5 decimals of pond area under tilapia farming. Farmers were able to produce tilapia twice a year. Our estimates reveal a substantial difference in farm income between the trained and non-trained farmers. The annual farm income of trained farmers was more than double that of the non-trained farmers. This income advantage reflects the benefits of adopting enhanced management practices, increased use of inputs, and higher stocking of fingerlings associated with the semi-intensive system.

Our results corroborate those of Widowati et al. (2021), who showed that the aquaculture field school resulted in the adoption of liquid compost technologies in the pond, increased shrimp and milkfish yield, and income of Central Java (Indonesia) farmers. Ragasa et al. (2022) demonstrated that participants in the training cohort exhibited significantly higher adoption of improved tilapia technologies and higher incomes compared to non-participants in Ghana.

Figure 2. Comparison of Annual Farm Income for an Average Tilapia Farm in 2015/16.

Source: Authors' calculation.

4. Conclusion

Researchers and policymakers are increasingly focused on understanding the impacts of farmer training programs, recognizing their potential to enhance farm productivity, income, and rural development. This study highlights the pivotal role of farmer training and institutional credit in driving the adoption of improved aquaculture technologies in Sylhet, Bangladesh. Specifically, training and access to credit are identified as the two most influential factors in the adoption of improved (semi-intensive) tilapia production systems. Training alone increases the likelihood of adoption by 79 percentage points, while access to credit contributes to 47 percentage points. When combined, these interventions can result in an almost universal adoption rate of 99.7%, underscoring the synergistic impact of technical knowledge and financial support in promoting aquaculture innovation.

The study further reveals that trained farmers achieve markedly higher productivity and profitability. Their average yield (5,225 kg/ha) exceeds that of non-trained farmers by 77.5%, while their net return (Tk. 296,674/ha) is 137% higher. Trained farmers also exhibit lower unit production costs (Tk. 38.96/kg) and a higher benefit-cost ratio (2.46), reflecting more efficient resource use and better management. Consequently, their annual farm income is more than double that of non-trained farmers, confirming the substantial benefits to their livelihoods from knowledge-induced aquaculture practices.

From a policy standpoint, these results underscore the need to prioritize farmer capacity-building as a cornerstone of sustainable aquaculture development. Government agencies, extension services, and non-governmental organizations should collaborate to design and implement targeted, hands-on training programs focusing on pond management, feed optimization, and input efficiency. Equally critical is the expansion of affordable institutional credit through coordinated efforts between financial institutions and aquaculture departments. Integrating technical training with access to credit will create enabling conditions for smallholder farmers to adopt improved technologies, enhance productivity, and sustain profitability. Continued investment in such integrated support mechanisms will accelerate the transition toward a more productive, inclusive, and resilient aquaculture sector in Bangladesh.

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