

## Technical Efficiency of Milkfish Pond Farming Using Traditional and Semi-Intensive Technology in West Java

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### ABSTRACT

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Efforts to increase milkfish production through efficient resource use are very important to study to provide alternatives for farmers in managing a milkfish pond business. It aims to increase production by using existing inputs so as to reduce farming costs and increase farmers' income. Specifically, the objectives of this study are (1) to describe the performance of the milkfish pond cultivation in both traditional and semi-technical production technologies, (2) to analyze the technical efficiency of the milkfish pond cultivation on both production technologies, and (3) identify the factors which affects the technical efficiency of the milkfish pond cultivation. This study used 2013 Agricultural Census data with a total of 1015 respondents of milkfish farmers in West Java Province. Data analysis was performed using descriptive and quantitative analysis. Descriptive statistical analysis was used to describe the characteristics of the respondents' activity, the socio-economic conditions of farmers, the use of production inputs from the milkfish pond cultivation. Quantitative analysis is used to analyze technical efficiency using the Data Envelopment Analysis (DEA) approach and to identify socio-economic factors that affect technical efficiency using the Tobit regression. The results showed that the milkfish pond cultivation in West Java Province in general is still cultivated traditionally (56 percent). The results also showed that the technical efficiency value of milkfish farmers with efficient traditional technology was 38 percent of the total farmers who cultivated traditionally with an average technical efficiency value of 0.7, while the milkfish farmers using semi-intensive technology were 22 percent of the 449 farmers. which uses semi-intensive technology with an average technical efficiency value of 0.6. The observed inefficiency may be attributable to suboptimal input allocation, although further analysis is required to establish a causal relationship.

### INTRODUCTION

Milkfish pond aquaculture (*Chanos chanos*) in West Java, particularly along the northern coastal corridor such as Karawang and Indramayu, has long served as an important pillar of food fish supply, a source of income for coastal households, and a driver of local fisheries-based economic activity. Milkfish accounts for 45.65 percent of total pond aquaculture production, while black tiger shrimp, which is an export commodity, contributes only 15.93 percent (Ichdayati et al., 2013). Initially, milkfish was cultivated under a monoculture system; however, to reduce the risk of crop failure, it has increasingly been cultivated in polyculture with shrimp (Lu YH et al., 2022). In Indonesia, milkfish remains one of the leading brackishwater pond commodities, whereas black tiger shrimp remains a high-value export-oriented aquaculture commodity (Jaya, 2026; Hartanti et al, 2024; Nompo et al, 2024).

Milkfish pond farming has strong development potential for two main reasons. First, the area of pond land that remains unused reaches 70.7 percent of the total pond area in

Indonesia (KKP, 2024). This land availability presents considerable potential for expanding milkfish farming. Second, demand for milkfish products continues to increase in both domestic and international markets, including the Philippines, Malaysia, Singapore, and Taiwan. This trend is also supported by the continued growth of the fish processing industry in Indonesia, in line with rising consumer preferences for fish and fish-based products.

In line with the growing demand for milkfish, increasing milkfish production and productivity in Indonesia has become increasingly important. In general, milkfish farming is carried out by pond farmers. Efforts to increase production can be pursued through land expansion (extensification), technological improvement (intensification), and the efficient use of resources (Bakhsh et al., 2006). Both extensification and intensification have been widely applied to increase milkfish production in Indonesia. Nevertheless, several opportunities and challenges remain in improving milkfish output through these two approaches. First, increasing production through extensification is potentially feasible because pond land utilization in Indonesia is still relatively low, at only around 22 percent of the total potential pond area. However, this extensification program faces a major challenge, namely the conversion of agricultural land (ponds) into non-agricultural uses.

Second, increasing production through intensification also has strong potential because it has already been adopted by milkfish farmers in Indonesia. However, this intensification program faces constraints, particularly limited access to capital, since adequate capital is needed by farmers to purchase supplementary feed and increase stocking density. In addition, although intensification can raise milkfish productivity by as much as 100 percent compared with traditional technology (Ula, 2017, milkfish productivity in Indonesia under semi-intensive technology remains low, at only 921 kg/ha. In the Philippines, milkfish productivity under traditional technology reaches 800–4,000 kg/ha. The low productivity of milkfish farming in Indonesia, under both traditional and semi-intensive technology, is suspected to stem from inefficient input use.

Based on this background, examining efforts to increase milkfish production through the efficient use of resources is highly important in order to provide farmers with alternatives for managing milkfish pond enterprises. This is expected to increase output using existing inputs, thereby reducing production costs and increasing farmers' income. In addition, the factors affecting the efficiency of milkfish farming such as farmers' socio-economic characteristics, also need to be examined, since these factors are also suspected to influence farmers' income levels. Specifically, the objectives of this study are to: (1) describe the performance of milkfish pond farming under two production technologies, namely traditional and semi-intensive systems; (2) analyze the technical efficiency of milkfish pond farming under these two production technologies; and (3) identify the factors affecting the technical efficiency of milkfish pond farming.

## **METHOD**

This study used 2013 Agricultural Census data with a total of 1015 respondents of milkfish farmers in West Java Province. Data analysis was conducted using both descriptive and quantitative approaches. Descriptive statistical analysis was used to describe the characteristics of respondent farmers, the socio-economic conditions of farmers, and the performance of production input use in milkfish pond aquaculture. Quantitative analysis was employed to analyze technical efficiency using the Data Envelopment Analysis (DEA) approach and to identify the socio-economic factors affecting technical efficiency using Tobit regression.

This study applies Data Envelopment Analysis (DEA), a non-parametric method used to evaluate the relative production efficiency of each decision-making unit (DMU). DEA was selected instead of Stochastic Frontier Analysis (SFA) because the present study does not aim to impose a specific functional form on the production technology, nor does it require distributional assumptions regarding inefficiency and statistical noise. This approach is particularly appropriate when the objective is to compare the relative performance of homogeneous producers based on multiple input–output combinations in a flexible analytical

framework. In this context, DEA provides a practical and robust tool for identifying efficient and inefficient production units without strong a priori parametric restrictions. According to Coelli et al. (2005), DEA operates by using linear programming techniques to construct a non-parametric efficiency frontier. DEA consists of two main approaches, namely CRSTE (Constant Returns to Scale Technical Efficiency), often referred to as DEA-CRS, and VRSTE (Variable Returns to Scale Technical Efficiency), or DEA-VRS. In the view of Benicio and de Mello (2015), the CRSTE or CCR model is based on the assumption that an increase in inputs will result in a directly proportional increase in outputs. Meanwhile, the VRSTE or BCC model is used to evaluate technical efficiency by taking into account variations in the effects of external factors, so it does not require a proportional relationship as assumed in the CCR model. The following presents the input-oriented BCC (VRSTE) model based on Coelli et al. (2005).

$$\text{Min}_{\theta, \lambda} \theta$$

Subject to:

$$\begin{aligned} -q + Q\lambda &\geq 0; \\ \theta x_i + X\lambda &\geq 0; \\ N'1'\lambda &= 1 \\ \lambda &\geq 0; \end{aligned}$$

Where  $\theta$  represents the technical efficiency value of a DMU,  $\lambda$  denotes the weight assigned to each DMU,  $q_i$  is the output of the  $i$ -th DMU, and  $Q$  is the total output multiplied by the corresponding weights.  $X$  refers to the total input multiplied by the corresponding weights. Furthermore, to address the third objective, a Tobit regression analysis was employed. Tobit analysis is used for dependent variables whose values are censored, as it accommodates the limited nature of the observed dependent variable by accounting for the concentration of observations at a lower or upper threshold. This makes the Tobit model more suitable than ordinary least squares for estimating relationships involving censored outcomes. Through this analysis, the factors affecting the technical efficiency of milkfish farming in Indonesia can be identified. In this study, seven independent variables were used, namely farming technology, gender, family size, years of education, participation in farmer groups, access to credit, and farmers' age. The Tobit regression equation is presented in Equation 2.

$$\begin{aligned} TE = \beta_0 + \beta_1 \text{Tech} + \beta_2 \text{Gender} + \beta_3 \text{Fam} + \beta_4 \text{Educ} + \beta_5 \text{Coop} + \beta_6 \text{Access Credit} \\ + \beta_7 \text{Usia} + e \end{aligned}$$

## RESULT AND DISCUSSION

### Descriptive analysis of farmers' characteristics

Table 1 presents the descriptive statistics of the variables used in this study. In general, milkfish pond farming in the sample is managed by middle-aged farmers with relatively low formal education, moderate household dependency, limited institutional participation, and a strong reliance on self-financing. These characteristics matter because technical efficiency in aquaculture is not shaped by production technology alone, but also by farmers' human capital, household conditions, and access to organizational and financial support. Prior aquaculture studies show that age, education, and managerial capacity are closely related to technical efficiency, while decision-making structure within the household may also affect farm performance (Islam, et al., 2024).

The cultivation technology variable had an average of 0.42 with a standard deviation of 0.49. This indicates that 42 percent use semi-intensive technology, while the remainder use traditional technology. Traditional technology is still widely adopted by farmers because this cultivation system is operationally simpler, relies largely on natural pond fertility and low external inputs, and therefore requires less capital, time, and managerial effort than feed-based systems. This interpretation is consistent with recent studies. Handayani et al. (2026) note that traditional milkfish ponds remain widely practiced by small-scale farmers because they

Table 1. Farmers' characteristics

Variable	Mean	Std. Dev
Technology (1= semi-intensive, 0=traditional)	0.42	0.49
Age (year)	46.87	10.69
Gender (1=male, 0=female)	0.95	0.21
Education (tahun)	4.78	4.30
Number of households	3.97	1.46
Farmer groups (1=Yes, 0=No)	0.09	0.29
Capital source (1=own, 0=others)	0.79	0.41

Source: Processed Data (2025)

require relatively low capital and use natural pond fertility as the main feed source. Similarly, Riany et al. (2023) show that traditional non-fed milkfish farming requires less capital and less effort or time investment than "traditional plus" systems, in which feed becomes a major cost component. Nagel et al. (2024) also describe traditional pond aquaculture as extensive, low-stocking, and low-input. Thus, the continued use of traditional technology should be understood not merely as technological conservatism, but as a rational response to the capital and livelihood constraints faced by smallholders. Although semi-intensive technology has been proven to produce higher yields, its use requires additional inputs such as feed and windmills, which can increase production costs. Furthermore, farmers require adequate managerial skills to manage such cultivation efforts. Research by Suharno et al. (2017) also showed that milkfish pond cultivation using traditional technology remains technically inefficient, so there is potential to increase production through better management and improved cultivation technology.

The next variable is farmer age, with an average of 46.87 years and a standard deviation of 10.69. This indicates that the majority of milkfish pond farmers are of productive age. The age of the farmers reflects their experience in cultivation. Older farmers tend to be slower in adopting management practices and technology because age is often associated with stronger reliance on conventional production routines, lower risk tolerance, and reduced flexibility in adjusting to new knowledge and farming methods. As a result, older farmers may be less responsive to innovations that require changes in input use, farm management, or decision-making strategies. Furthermore, in terms of gender, 95 percent of milkfish farmers are male. Islam et al. (2024) showed that younger farmers with higher education tend to be able to allocate inputs more efficiently, thus influencing the technical efficiency of their farming businesses.

In terms of formal education attained by farmers, the majority attained elementary school (SD), with an average of 4.78 years of education, with significant variation among farmers. This level of education reflects farmers' ability to access information, technology, production options, and implement efficient management practices. Islam et al. (2024) showed that higher education is associated with better input use, stronger managerial performance, and greater adoption of modern agricultural technology. The relatively low average education level indicates potential structural constraints to increasing technical efficiency (Islam et al., 2024).

Milkfish farming households have an average number of dependents of 3.97 and a standard deviation of 1.46, indicating that most respondents support approximately four family members. This situation can have two-way effects. On the one hand, larger households can provide family labor, helping reduce the cost of outside labor, especially in more traditional production systems. On the other hand, greater household dependency can increase consumption pressures and reduce farmers' ability to invest in productivity-enhancing inputs. Therefore, household size is relevant as a determinant of technical efficiency.

In milkfish farming, some farmers join farmer groups to share information related to cultivation activities, access technology, and access government assistance. However, the number of farmers who join farmer groups is relatively low, with only 9 percent involved. This

low participation rate indicates that most farmers operate individually, with potentially limited access to collective learning, extension services, and information exchange among farmers. Research by Islam et al. (2024) shows that institutional participation and support networks are often associated with increased productivity, better knowledge dissemination, and stronger adoption of better practices. Therefore, the weak participation of farmer groups in this sample may help explain differences in technical efficiency across farms.

Milkfish farming activities not only rely on their own capital, but farmers also access external capital. Seventy-nine percent of respondents used their own capital, while only 21% used borrowed funds. This indicates that self-financing is the dominant mode of operation. While this may reflect financial prudence, it may also indicate limited access to formal or informal credit. This is relevant because the adoption of more advanced technologies often requires greater capital investment, and recent evidence suggests that financial constraints remain a major barrier to technological upgrades in fish farming. In this regard, reliance on own capital may not be simply a financial preference but reflects limited investment capacity, which can ultimately impact technical efficiency (Islam et al., 2024).

Overall, descriptive statistics indicate that milkfish pond farming in the study area is characterized by male-dominated farm management, relatively low levels of education, moderate household dependence, weak institutional participation, and high reliance on self-financing, while traditional technologies still dominate most farms. This situation implies that differences in technical efficiency are likely driven by more than just the type of production technology.

### Descriptive Analysis of Input Production

The main distinction between traditional and semi-intensive milkfish farming lies in the intensity of production input use. Semi-intensive culture is generally characterized by higher stocking densities, greater use of fertilizers, the application of supplementary feed, and increased labor requirements, whereas traditional culture relies more heavily on natural food availability within the pond. In milkfish aquaculture, this transition from traditional to semi-intensive production is commonly understood as a process of intensification, in which higher biological and material inputs are used to increase output per unit area.

Table 2. The average use of production inputs per hectare

Input Type	Unit	Technology Traditional (n = 566)	Semi-intensive (n = 449)
Fry	fish/ha	10,229.25	26,584.95
Urea	kg/ha	56.01	79.97
TSP	kg/ha	16.55	52.64
Family labor	labor-days/ha	146.17	198.66
Hired labor	labor-days/ha	23.64	24.25
Feed	kg/ha	0.00	328.46

Source: Processed Data (2025)

As shown in Table 2, the average use of production inputs per hectare was consistently higher in semi-intensive ponds than in traditional ponds. Stocking density reached 10,229.25 fry/ha in traditional systems and 26,584.95 fry/ha in semi-intensive systems. Likewise, the use of urea increased from 56.01 kg/ha in traditional ponds to 79.97 kg/ha in semi-intensive ponds, while TSP use rose sharply from 16.55 kg/ha to 52.64 kg/ha. Labor use followed a similar pattern. Family labor (TKDK) increased from 146.17 HOK/ha under traditional technology to 198.66 HOK/ha under semi-intensive technology, while hired labor (TKLK) was relatively similar between the two systems, at 23.64 and 24.25 HOK/ha, respectively. The most striking difference was observed in feed use: traditional farmers did not apply commercial feed, whereas semi-intensive farmers used an average of 328.46 kg/ha. This pattern indicates that semi-intensive milkfish farming involves a shift from sole dependence on naturally available

pond productivity toward a combined strategy based on natural food and supplementary feeding. Previous studies likewise show that supplemental feeding in brackishwater milkfish ponds can enhance growth, production, and economic returns, although such gains depend on feed quality, feeding rates, and pond management.

Milkfish farmers adopting traditional technology have an average pond size of 2.27 hectares, while farmers adopting semi-intensive technology have an average pond size of 2.39 hectares. Traditional pond farmers mostly manage ponds measuring 1-2 hectares, while those using semi-intensive technology manage between 2 and 3 hectares. This indicates that farmers adopting modern technology have larger ponds to support input intensification and production management. Although the adoption of semi-intensive technology tends to be managed in larger ponds, this does not guarantee higher technical efficiency, as this efficiency is highly dependent on the farmer's ability to allocate inputs, seed stocking density, feed provision, labor allocation, and water quality (Sumagaysay et al., 2003).

In terms of land ownership, the majority of milkfish farmers manage their own ponds (56.16 percent), while 53.53 percent manage rented ponds. In terms of cultivation technology, 53.53% of independently owned and managed ponds use traditional technology, while 59.02% use semi-intensive technology. This ownership structure is relevant because semi-intensive cultivation requires higher cash expenditures, particularly for seed, fertilizer, and feed. Therefore, farmers who own their own ponds tend to have greater decision-making flexibility and a stronger incentive to invest in technology than those who rent.

The fundamental difference between these two technologies is seed stocking density. Farmers adopting traditional technology generally use lower seed stocking densities than those using semi-intensive technology. In traditional technology, milkfish production tends to be determined by the productivity of natural ponds supported by fertilization, while semi-intensive systems combine natural food with supplemental feed and can therefore maintain higher stocking densities.

In terms of seed use, many milkfish farmers in West Java Province, both traditional and semi-intensive, use seed below the recommended stocking density of 3,000-6,000 fish per hectare. Most farmers stock less than 3,000 per hectare, and some even exceed the recommended number, reaching up to 18,000 per hectare. This sub-optimal seed use is suspected to impact suboptimal land productivity. Semi-intensive milkfish farmers also use seed densities that are below recommended, and many milkfish farmers even use seed exceeding the recommended levels. This excessive seed use negatively impacts the milkfish's growth, leading to oxygen deprivation and health issues, including stress and even death.

Changes in milkfish pond cultivation technology have also led to increased labor requirements. Semi-intensive technology generally requires more labor, especially for maintenance and harvesting. In general, the use of family labor (TKDK) in traditional milkfish cultivation reaches 86 percent, while in semi-intensive cultivation it reaches 86 percent. The high use of TKDK is thought to be due to the relatively large number of family members in farming families, which provide a significant labor source for milkfish production. This situation indicates that milkfish cultivation in West Java is largely household-based. The strong reliance on family labor indicates that household members continue to serve as the primary labor source to reduce production costs. However, the higher use of family labor under semi-intensive technology indicates that intensification increases not only cash needs but also daily operational demands, particularly for pond maintenance, feeding, and harvesting activities. Thus, the transition to semi-intensive production should be understood not only as a technological shift but also as a reorganization of household labor and farm management.

Other important inputs in milkfish farming are feed and fertilizers. In semi-intensive ponds, the average use of pelleted feed reached 328.46 kg/ha, while no artificial feed was used in traditional ponds. Some farmers also reported using expired bread as a low-cost supplementary feed. Biologically, feed supplementation can accelerate fish growth and shorten the production cycle, particularly when combined with higher stocking densities and better pond management. However, feed-based intensification also raises production costs and places

greater pressure on pond water quality. Previous studies have shown that supplemental feeding can improve milkfish growth and profitability, but excessive feed input may also contribute to nutrient buildup and oxygen stress in ponds. At the same time, fertilization with urea and TSP remains important in both systems because it stimulates the growth of plankton and benthic algae as natural food sources. Thus, the difference between traditional and semi-intensive milkfish culture is not simply that one system uses “more inputs” than the other, but that each system organizes seed, feed, fertilizer, and labor in a different production strategy with different cost structures, risks, and management requirements (Kühlmann et al., 2008).

Overall, the evidence suggests that semi-intensive milkfish farming represents a strategy of output expansion through input intensification, particularly in terms of fry, fertilizers, feed, and family labor. Yet this intensification comes with trade-offs. On the one hand, it offers greater potential for faster growth and higher production. On the other hand, it requires larger cash outlays and more careful control of water quality and pond carrying capacity. For this reason, farmers who remain in traditional systems should not automatically be viewed as technologically lagging. In many cases, their choice may reflect a rational economic response to capital constraints, production risk, and limited managerial capacity at the farm level (Sumagaysay. et al.,1991; 2003).

### Technical Efficiency of Milkfish Pond Farming

The analysis using the DEA approach, assuming variable returns to scale technical efficiency, shows that the majority of milkfish farmers in West Java have a technical efficiency of less than one: 700 farmers (68.97 percent), consisting of 350 traditional farmers (61.84 percent of the total traditional farmers) and 350 farmers using semi-intensive technology (77.95 percent of the total semi-intensive farmers). This indicates that farmers using traditional technology tend to use inputs more economically or according to production capacity, while semi-intensive farmers may experience over-input without a proportional increase in output. This could be due to limited technical knowledge and the inappropriate application of modern technology, as improved aquaculture practices generally require adequate training, extension support, and proper adaptation to pond conditions in order to generate productivity gains (Rahman et al., 2023; Tarunamulia & Sammut, 2023).

This finding aligns with Den et al. (2007) and Kiet et al. (2011), and is reinforced by recent studies such as Rahman et al. (2020), which show that traditional systems are often more efficient due to management simplicity and suitability to local conditions. However, the study by Hakim et al. (2022) and Kusnandar et al. (2021) showed that efficiency in semi-intensive systems can be significantly increased by optimizing inputs, training farmers, and improving access to technology. Research by Rahman and Sarker (2020) stated that technical efficiency is influenced not only by the type of technology but also by the farmer's management capacity to adopt and implement the technology.

Table 3. Results of DEA calculation under the Variable Returns to Scale Technical Efficiency (VRSTE) assumption

Description	Traditional	Semi-intensive
Average technical efficiency score	0.70	0.60
Maximum	1.00	1.00
Minimum	0.11	0.14
Number of farmers with an efficiency score equal to one	216.00	99.00
Number of farmers with an efficiency score less than one	350.00	350.00

Source: Processed Data (2025)

Improvements in technical efficiency in milkfish farming can be achieved by using production inputs in accordance with recommended levels. Several inputs require particular attention from farmers, especially stocking density, which remains below the recommended level. Based on the input slack results, stocking density in both traditional and semi-intensive

technologies was still below the recommended standard. In traditional milkfish culture, stocking density needs to be increased by 883 fry, while in semi-intensive culture it needs to be increased by 4,212 fry. This finding is consistent with Iliyasa et al. (2016), who reported that all inputs used in the production process across various aquaculture systems and species may contain inefficiencies and therefore need adjustment. Feed, which is the main input in fish production and accounts for more than half of total production costs, is also often used excessively. Other findings also reveal that milkfish production in Indonesia is generally inefficient because, potentially, output could still be increased by using certain inputs in more appropriate combinations (Suharno et al., 2017).

Table 4. Average input slack values of all respondent farmers

Variable	Traditional		Semi-intensive	
	Average slack value	Percentage of respondents	Average slack value	Percentage of respondents
Fry (fish)	883.53	13.07	4212.29	41.52
Family labor (labor-days)	3.89	6.39	2.89	5.36
Hired labor (labor-days)	6.80	37.81	7.63	24.33

Source: Processed Data (2025)

### Factors Affecting the Technical Efficiency of Milkfish Pond Farming

Second, the Tobit regression results indicate that the factors significantly affecting the technical efficiency of milkfish pond farming in West Java are production technology, farmer age, farmer group membership, and the source of capital used by farmers (Table 5). Semi-intensive technology has a negative coefficient on efficiency ( $\beta = -0.077$ ;  $p < 0.01$ ), indicating that the use of more modern technology does not automatically improve efficiency without proper input adjustment. Although production technology affects efficiency, the coefficient suggests that farmers applying semi-intensive technology tend to exhibit lower efficiency levels. This is supported by field conditions showing that input use under semi-intensive technology has not yet fully complied with recommended practices, particularly with respect to seed stocking density, which remains below the recommended level.

External capital sources also have a negative effect on technical efficiency ( $\beta = -0.057$ ;  $p < 0.01$ ), possibly because of dependence on inflexible financing schemes or pressure to increase production without sufficient attention to input efficiency. In contrast, farmer group membership has a positive and significant effect on the technical efficiency of milkfish farming ( $\beta = 0.229$ ;  $p < 0.01$ ). This finding highlights the importance of institutions in supporting learning processes and information exchange among farmers. Farmers who participate in farmer groups tend to achieve higher technical efficiency because such groups also provide guidance on the appropriate use of inputs according to the production technology applied. This result is consistent with the findings of Barus et al. (2023) and Supadi et al. (2021), who reported that institutional participation and access to technical training can enhance efficiency. Likewise, Iliyasa et al. (2016) found that fish farmers who receive extension services tend to be more efficient, likely because they can more easily learn about new or improved technologies.

Farmer age also shows a negative effect on technical efficiency ( $\beta = -0.002$ ;  $p < 0.05$ ), indicating the importance of farmer regeneration and greater involvement of younger farmers. Previous studies by Supadi et al. (2021) and Barus et al. (2023) also found that technical efficiency is associated with age and access to training. This finding points to the need for younger generations to enter the sector. However, a major challenge is that farmers' children are often reluctant to continue their parents' farming businesses and instead prefer to work outside the region or in urban areas. This result also supports the findings of Cinemre et al. (2006), who identified age and education as important determinants of technical efficiency. Similarly, Iliyasa et al. (2016) reported that younger farmers are generally more willing to

accept new knowledge, invest in technological development and adoption, and improve their farming practices. See et al. (2021) further suggested that, in order for young farmers to gain useful experience, they should receive training in supervision and agricultural production management.

Table 5. Factors Affecting the Technical Efficiency of Milkfish Pond Farming

Variable	Coefficient	Std. Error	Prob.
Technology	-0.077***	0.018	0.0000
Gender	-0.022	0.040	0.5872
Number of dependents	-0.001	0.006	0.8572
Education level	0.002	0.002	0.2875
Farmer group membership	0.229***	0.032	0.0000
Source of capital	-0.057***	0.021	0.0063
Farmer age	-0.002**	0.001	0.0550
Constant	0.839	0.066	0.0000

Source: Processed Data (2025)

\*\*\*, \*\*: significant at the 1% and 5% levels, respectively.

The coefficient of education has a positive effect on technical efficiency, although it is not statistically significant. As farmers' education levels increase, the positive role of education in improving technical efficiency has also been reported in previous studies (Onumah et al., 2018; Begum, 2013; Oluwatayo et al., 2019). The rationale is that more educated farmers generally possess better skills, greater access to information, and stronger farm management capabilities. Higher education levels may increase farmers' capacity to use knowledge for making regular and informed investments in the management of their farming operations. However, Chiang et al. (2004) found that education level had a significant negative effect on technical efficiency. This suggests that a high level of formal academic education may not always be directly beneficial for farmers, whereas more specific formal training, such as aquaculture training, may be more relevant and useful.

Overall, although semi-intensive technology is intended to increase productivity, its application without adequate technical and managerial capacity may instead lead to inefficiency. Therefore, strategies to improve efficiency should not depend solely on the type of technology adopted, but also on strengthening technical knowledge, improving farmer institutions through fish-farming groups, and expanding access to financing schemes that support efficient production.

## CONCLUSION

Milkfish pond cultivation in West Java Province is largely still carried out traditionally due to farmers' limited access to capital for semi-intensive technology. Based on technical efficiency scores, milkfish farmers using efficient traditional technology account for 38 percent of the total, with an average technical efficiency score of 0.7. Meanwhile, milkfish farmers using semi-intensive technology account for 22 percent of the 449 farmers using semi-intensive technology, with an average technical efficiency score of 0.6. The low efficiency of milkfish farmers is due to the fact that input use, particularly seed stocking density and feeding, is still below recommended levels. The technical efficiency of milkfish pond cultivation is negative and significantly influenced by cultivation technology and farmer group participation, while capital resources and farmer age have a negative influence.

The analysis of technical efficiency factors in milkfish pond cultivation indicates that farmer groups play a crucial role in increasing farmer knowledge in milkfish cultivation management, thus optimizing farmer group activities. The results of the study show that semi-intensive technology produces a lower level of technical efficiency because farmers have not yet mastered it well and ultimately the use of inputs becomes excessive, so that it is related to

the findings of this study that the role of farmer groups in disseminating pond cultivation technology is very important to be improved.

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