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Determinants of Production and Technical Efficiency of Tilapia Farming in the Philippines

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

The Philippines' economy depends heavily on the profitability of the tilapia aquaculture industry. The country's tilapia aquaculture still has a significant amount of untapped biophysical growth potential; therefore, more rapid expansion is needed to keep up with the increasing demand for fish. The study examined the variables affecting the technical efficiency of tilapia production in the Philippines. The face-to-face interview method was used to survey randomly selected tilapia farms. The efficiency of the Philippines' tilapia aquaculture was estimated in this study. Overall, the findings of the technical efficiency analysis indicated that all fish producers within the examined regions were functioning below the production frontier. Therefore, to boost productivity and efficiency, it is necessary to thoroughly study the origins of inefficiencies in socioeconomic variables and farm features. The mean technical efficiency, as determined by the maximum likelihood estimation of the stochastic production frontier, is 0.44. The model's outcome showed

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that area and stocking rate significantly impact tilapia output in a few selected Philippine locales. It was discovered that factors such as the utilization of aeration, adoption of advanced culture method, and access to government support are significant predictors of technical efficiency in tilapia farming. The policy implication is that there are still more opportunities to raise the current level of technical efficiency of tilapia production in the Philippines.

Keywords: Technical efficiency; aquaculture; tilapia farming; socioeconomic.

1. INTRODUCTION

The Republic of the Philippines with a population of about 110 million is one of the largest consumers of fish in the world. According to SEAFDEC [1], in 2021 each Filipino consumed an average of 34.28 kg of fish and fishery products per year. However, domestic fisheries production in the country which was estimated at about 4.40 million metric tons in 2020 is much lower than the local demand, thus, obliging the government to import fish and fishery products from other countries [1]. If aquaculture is to be part of the solution and provide affordable, accessible food products, it needs to be developed in a sustainable way [2]. The task of bridging the wide gap between demand and supply of fish product in the Philippines remains massive [3]. The target of increasing animal protein supply in the country can be achieved through improving the productivity and efficiency of farms [2].

Productivity in its most elemental definition is a ratio of outputs to inputs, with a more productive unit achieving higher outputs for a given set of inputs [4]. The efficiency of a production unit, on the other hand, is a comparison between observed and optimal values of its output/input combinations [5]. A production unit is more efficient the closer it is to the frontier for its technology [6]. Hence, efficiency and productivity are indicators of how producers are making use of different inputs to obtain outputs.

Aquaculture productivity is commonly measured as total biomass [7]. However, in many cases, additional parameters are required to make comprehensive studies [8]. Ahaz [9] stated that simple algebraic models can be used to make important decisions in farms. These methods are relatively easy to carry out and their implementation requires a basic mathematical background. In scientific research, they can be used to compare similar experimental procedures [10].

Technical efficiency (TE) is defined by Kumbhakar and Lovell [11] as the ability of a decision-making unit (DMU) to obtain the maximum output from a set of inputs (output orientation) or to produce an output using the lowest possible number of inputs (input orientation). TE, its measurement, and the factors determining it are of crucial importance in production theory. The technical efficiency of a DMU and the degree of use of variable inputs determine the output and capacity utilization. Determining those factors affecting it allows stakeholders to take measures to limit or improve it. Farrell [4] defined technical efficiency as the ability to produce a given level of output with a minimum quantity of inputs under certain technology. Moreover, the demographic makeup, economic conditions related to production and investment, as well as the income and spending habits of individuals residing in a specific area significantly influence how they react to technological advancements and engage in development initiatives [12].

The growing global popularity of tilapia among consumers and the ever-increasing need to improve food production impose the need to seek production alternatives and improvements in tilapia aquaculture [13]. Tilapia farming and utilization have not been fully explored as a strategy to reduce poverty levels despite their potential to improve livelihoods in rural communities. Low productivity, high farm-level production inefficiency, significant post-harvest losses, and lack of appropriate production knowledge often pose problems [14]. Therefore, this study aims to determine the productivity, profitability, level of technical efficiency, and bio-economic model of tilapia aquaculture farms in selected areas in the Philippines.

2. MATERIALS AND METHODS

2.1 Study Sites

Twelve provinces in the Philippines (Fig 1) were randomly selected for this study. These provinces include Negros Oriental, Nueva Ecija, Iloilo, Pampanga, Palawan, Cagayan, Davao

(Province), South Cotabato, Cebu, Batangas, Mindoro, Agusan del Norte A stratified sampling technique was employed to categorize the tilapia farming methods in each selected area into strata, specifically cages and ponds, to ensure a homogeneous distribution of the population. Subsequently, the sample respondents were selected using simple random sampling from the list of tilapia fish farmers obtained from the Bureau of Fisheries and Aquatic Resources (BFAR). A total of 75 farmers were subjected to a key informant interview (KII).

2.2 Data Collection

The data for this study were collected using a questionnaire and key informant interviews (KIIs) with selected tilapia farmers. Information was gathered on their production input usage over a single production season, as well as the outputs produced. Table 1 presents a summary of statistics pertaining to the variables included in the stochastic frontier production and technical inefficiency models for Tilapia farming.

Table 1. Summary statistics for variables included in the stochastic frontier production and technical inefficiency models for tilapia farming

Variable	Definition	Measurement
Output and input variables		
X^1	Area	Hectare (ha)
X^2	Stocks	Pieces (pcs)
X^3	Labor	Man-days (days)
X^4	Feeds	Kilograms (kg)
X^5	Fuel	Liters (l)
X^6	Machineries (operational)	Hours used (hrs)
X^7	Medicine	Milligrams (ml)
Farm Specific Variables		
Z^1	Age	Years
Z^2	Household Size	Number of individuals
Z^3	Farm Experience	Years
Z^4	Years in School	Years
Z^5	Access to Gov't Facilities/Assistance/Trainings	Dummy: (1-yes, 0-otherwise)
Z^6	Use of Aerator	Dummy: (1-yes, 0-otherwise)
Z^7	Water Source	Dummy: (1-pump,0- otherwise)
Z^8	Gender	Dummy: (1-male, 0-otherwise)
Z^9	Culture method	Dummy: (1-yes, 0-otherwise)

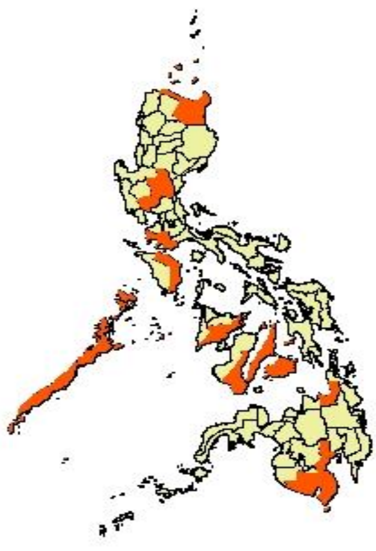

Fig. 1. Study sites (shaded in orange)

2.3 Research Instrument

Data were collected from randomly selected tilapia farms (cage and pond) using a survey questionnaire. The questionnaire was developed in English and can be translated into the local dialect if necessary. The survey was conducted face-to-face with the aid of the questionnaire. This method was chosen to gather people's responses and collect more in-depth information. Questions were simplified for ease of answering and data tabulation, ensuring that all pertinent information would be collected. The questionnaire was divided into several parts as follows:

I. Profile of the tilapia farmer
II. Farm information
III. Production technology and practices employed by the respondents
IV. Variable inputs and cost
V. Labor utilization and cost
VI. Capital investment
VII. Financing
VIII. Marketing practice
IX. Problems encountered and other significant information

2.4 Socio-Demographic Analysis

The descriptive method of analysis was employed to describe the fundamental socio-demographic characteristics of fish farmers and their existing farming practices. Averages, ranges, and percentages were utilized for this purpose.

2.5 Technical Efficiency Analysis

2.5.1 The cobb-douglas production function

The most commonly used production function is the Cobb-Douglas production function. This function is easy and convenient to estimate since it is linear in parameters. Data and other pertinent information were analyzed using appropriate methods and procedures, as described in the succeeding sections.

A pooled regression of all the farms was conducted. This approach has been commonly used to estimate differences in technical efficiency and is recommended when all the farms are producing the same commodity. Several studies have employed a pooled regression method [15-17].

2.5.2 Analysis of productivity

Production Function Analysis was utilized to analyze productivity in this study. This analysis aims to establish the physical relationship between output and the explanatory variables. This relationship will be expressed in the following generalized form:

$$Y = f(X_1, X_2, \ldots\ldots, X_n)$$

In this equation, output is denoted by Y, representing the weight of tilapia in kilograms, which is dependent upon the quantities of Total Stocks (number of fry), Hired Labor Input Used in Production (man-day), Feeds (in kilograms), Fuel (in liters), Machineries (number of hours used) during the production process. These inputs were expressed as $X_1, X_2, \ldots, X_n$

The stochastic frontier production function to measure technical efficiency of production was adopted from the methods of Aigner et al. [18], Meeusen and van den Broeck [19] and John et al [20]. Model of the stochastic frontier production for estimation of productivity is:

$$Ln(Y_i) = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \beta_7 \ln X_7 + \beta_8 \ln X_8 + V_i - U_i$$

Where:

Y = Production in kg per farm

X_1= Area of focus cages (ha)

X_2= Stocks (number of fry)

X_3= Hired labor use in production (man-day)

X_4= Feeds (kg)

X_5= Fuel (liters)

X_6= Machineries (number of hours used)

X_7= Medicine (ml)

ln= Natural Logarithm

V_i = The symmetrical part that represents the random errors linked to random factors controlled by fisheries farmers

U_i = The asymmetric error component indicates the deviation from optimal production, representing technical inefficiency.

V_i-U_i is the error term

2.5.3 Technical efficiency model

The study used inefficiency as the dependent variable; thus, variables with a negative (positive) coefficient sign will have a positive (negative) impact on technical efficiency.

$$Ui = \alpha_0 + \alpha_1 Z_1 + \alpha_2 Z_2 + \alpha_3 Z_3 + \alpha_4 Z_4 + \alpha_5 Z_5 + \alpha_6 Z_6 + \alpha_7 Z_7 + \alpha_8 Z_8 + \alpha_9 Z_9 + \alpha_{10} Z_{10}$$

Where:

U_i = Technical inefficiency

Z_1= Age

Z_2= Family/Household size

Z_3= Farming experience (in years)

Z_4= No. of years in school

Z_5= Access to Government Facilities and training (dummy, 1 if yes, 0 otherwise)
Z_6= Use of aerator

Z_7= Water source

Z_8= Gender

Z_9= Culture Method

αi's = Parameters to be estimated

3. RESULTS AND DISCUSSION

3.1 Characteristics of Tilapia Farms in the Philippines

Tilapia farms in the Philippines are commonly categorized into three culture system groups: cages, ponds, and tanks. Tanks are usually (but not always) operated as hatcheries, focusing mainly on producing tilapia fry. These farms serve as the source of fish supplying fry to tilapia grow-out farms. Hatcheries in the Philippines are either government-operated or private farms. The primary culture system in the provinces included in the study area is the grow-out tilapia pond culture, except for Batangas. The list of municipalities per province where the survey was conducted is shown in Table 2.

3.1.1 Stocking practices

Most farms strategically employ staggered stocking, using fingerlings ranging from size #22 to size #17. This practice allows for harvesting to be scheduled at regular intervals, providing farmers with a consistent income for daily family sustenance and covering expenses such as schooling allowances for their children and agricultural farm expenses.

3.1.2 Classification of ponds

Ponds are the most common method of fish culture [21], where water is contained in enclosed areas by artificially constructed ponds for Tilapia culture. In the Philippines, ponds are filled with spring water, pump water from deep wells, or irrigation water. Various types of constructed ponds (Fig 2) are utilized in the Philippines for Tilapia culture. Not all ponds in the country are constructed in a conventional rectangular shape; several dike designs are observed in the study areas. Some dikes are built with stones or boulders, some utilize bamboo to reinforce the dikes, and others use traditional soil dikes.

3.2 Socio-Demographic Characteristics of Respondents

The characteristics of the tilapia farmers studied included age, gender, civil status, educational attainment, household size, farming experience, and training in fish farming. These characteristics were analyzed using descriptive statistics. Table 3 presents the various socio-demographic variables and classifications within which the respondents are categorized.

3.2.1 Age of respondents

The result showed that the average age of Tilapia farmers in the selected areas in the Philippines is 53 years old. From the analysis of the age data in Table 4, the modal age of 51-60 years means that the majority of the fishery farmers interviewed were middle-aged or older. Additionally, 44% of the farmers belong to this age bracket. The youngest farmer is 23 and the oldest is 69 years old. Age is an important factor in traditional aquaculture. It determines a farmer's productive ability and consequently his output. This is because tilapia farming is still labor intensive in this part of the world and traditional agriculture production system relying on rudiments implements powered by human muscle [22]. Therefore, beyond a certain age, a farmer's productivity begins to decline.

Table 2. List of province, municipalities, farms, culture system, and source of water surveyed

Province	Municipality/City	No. of farms surveyed	Culture System	Source of water
Negros	La Carlota City	1	Pond Grow-out	Spring
	Bago City	1	Pond Grow-out	Deep well/Irrigation
	Isabela	1	Pond Grow-out	Spring
	Talisay	1	Pond Grow-out	Spring
Nueva Ecija	San Leonardo	1	Tank/Hatchery	Deep well/Irrigation
	Munoz	1	Pond Grow-out	Deep well/Irrigation
	Cabiao	1	Pond Grow-out	Deep well/Irrigation
	San Isidro	1	Pond Grow-out	Deep well/Irrigation
Iloilo	Miagao	1	Pond Grow-out	Deep well
	San Juaquin	1	Pond Grow-out	Deep well
Pampanga	Mexico	2	Pond Grow-out	River
	Minalin	2	Pond Grow-out	River
Palawan	Narra	4	Pond Grow-out	Spring
Cagayan	Tuao	1	Pond Grow-out	Deep well
	Solana	1	Pond Grow-out	Deep Well
	Penablanca	1	Pond Grow-out	Irrigation
	Iguig	1	Pond Grow-out	Deep well
Davao	E.B Dujali	3	Pond Grow-out	Irrigation/Pump
		2	Tank/Hatchery	Pump
South Cotabato	Banga	13	Cages Grow-out	Lake
		2	Tank/Hatchery	Deep well/Spring
Cebu	Aluguisan	1	Pond Grow-out	Deep Well
	Ronda	2	Pond Grow-out	Spring
	Moalboal	1	Pond Grow-out	Irrigation
	San Fernando	1	Pond Grow-out	Irrigation
Batangas	Agoncillo	10	Cage Grow-out	Lake
	Laurel	7	Cage Grow-out	Lake
Mindoro	Victoria	1	Pond Grow-out	Spring
	Nauhan	1	Pond Grow-out	River
	San Teodoro	1	Pond Grow-out	River
	Calapan	1	Pond Grow-out	Deep well
Agusan	Kitcharao	1	Pond Grow-out	Spring
	Cabadbaran	1	Pond Grow-out	River
	Magallenes	1	Pond Grow-out	Spring
	Jabonga	4	Cage Grow-out	River
	Butuan City	1	Pond Grow-out	Spring
Total		**75**		

Note: The five (5) hatchery farms (tanks) were not included in the Productivity and Technical efficiency analysis

There is a strong possibility that when older farmers retire from tilapia farming, there will be only a few young farmers left in the tilapia culture industry to continue the goal of producing fish and fishery products for consumers. As noted by Alam et al. [23] the age of farmers was a significant determinant of technical inefficiency for tilapia farms. However, it had a significant positive influence on technical efficiency, while conversely, it had an insignificant negative influence on tilapia farms.

3.2.2 Gender roles

This study showed that 14% of the respondents were female, indicating that aquaculture activities are still dominated by men. The results show that 86% of the farmers were male, likely because fish farming is a laborious and strenuous activity. However, there are now women who engage in actual fish farming and even own fishponds in the Philippines. The gender-segregated activities of Tilapia farmers in the Philippines are shown in Table 5.

In Southeast Asia, women in fishing households participate actively in fisheries activities, especially those related to post-harvest and trading. Women carry out tasks such as fish sorting, processing, pricing, and selling. The role of women in fisheries is often viewed as small-scale and home-based. In traditional fisheries, women are usually not directly involved in aquaculture activities. They are typically confined to tasks such as net making, processing, and marketing fish products [24].

As owner/operators, women manage the farm themselves while occasionally hiring laborers during pond preparation and harvest time. As operators, they are responsible for overseeing the operations of cage farming through different stages of development, from planning to construction, to operation, and up to marketing. One reason behind the involvement of women acting as farm managers is that their husbands may be managing other businesses, such as rice farms, or may be employed in plantations. Since their houses are within their farms, women involved in aquaculture can manage their fishponds without leaving the vicinity and can still perform their daily household chores.

Table 3. Socio-demographic characteristics of respondents

Variables	Classification	No. of Respondents	Percentage (%)
Age			
	20-29	5	7.14
	30-39	11	15.71
	40-49	10	14.28
	50-59	36	51.42
	60-69	8	11.42
Gender			
	Male	60	85.71
	Female	10	14.28
Educational Attainment			
	No formal Education	4	5.71
	Elementary	16	22.85
	High School	36	51.42
	Tertiary/College	11	15.71
	Graduate School	3	4.28
Civil Status			
	Single	9	12.85
	Married	53	75.71
	Widowed	8	11.42
	Separated	0	0
Household Size (no. of individuals)			
	2	4	5.71
	3	9	12.85
	4	11	15.71
	5 and more	46	65.71
Farming Experience (in years)			
	1-5	7	10.00
	6-10	11	15.71
	11-15	34	48.57
	16-20	13	18.57
	More than 20	5	7.14
Training in Aquaculture			
	With formal training	22	31.42
	No formal training	48	68.57

Table 4. Modal age grouping of tilapia farmers

Age Group	Frequency	Percentage (%)
Below 20	0	0.00
20-30	3	4.29
31-40	6	8.57
41-50	26	37.14
51-60	31	44.29
Above 60	4	5.71
Total	**70**	**100**

Table 5. Gender-desegregated activities of tilapia farmers

Activities	Male	Female
A. Household		
Cooking		X
Laundry	X	X
Washing dishes		X
House Cleaning	X	X
Water Gathering	X	X
B. Aquaculture		
Excavation of ponds	X	
Draining and Water refill of ponds	X	X
Dike repair	X	
Application of fertilizer	X	X
Feeding	X	X
Stocking	X	X
Cleaning of ponds	X	X
Harvest	X	X
Selling of Catch	X	X
C. Community Activities		
Political involvement	X	
Church activities (“Pasyon”, “prosisyon”)	X	X
Fiesta	X	X
Athletics	X	
Social gatherings (“sayawan”)	X	

Fig. 2. Various types of ponds used for tilapia culture in the study sites

According to FAO [25], the quality and frequency of reporting on engagement by gender improved slowly. It is estimated that, overall, women accounted for more than 19 percent of all people directly engaged in the fisheries and aquaculture primary sector in 2014. The result of this study (14% of the farmers are women) conforms to the figure given by FAO.

3.2.3 Educational attainment

The study revealed that respondents had modest educational attainment, with the majority of the farmers having reached the high school level. Although all the respondents are considered fish farmers, their degree of work or involvement on the farm varies. Literate farmers are expected to be more innovative because of their ability to obtain and comprehend information more quickly and their willingness to take more risks. Typically, farmers with a college degree or graduate degree holders are the owners or farm managers. Those with elementary or high school certificates are usually part of the hired labor category, though not exclusively.

Education is an important factor that affects the productivity of farmers, as it provides them with the opportunity to understand improved techniques designed to increase farm output and ensure efficiency. It also helps in raising awareness about the significance of various environmental conservation programs promoted by the government and the private sector [26]. At its most basic level, education is important because it provides people with essential skills. These skills include basic literacy and numeracy, as well as the ability to communicate, complete tasks, and work with others [27]. Therefore, education can guide fish farmers in making business decisions that improve efficiency on their farms.

3.2.4 Farming experience (in years)

There are several ways to learn about fish farming. First, one can work on an aquaculture farm to gain hands-on experience. Second, one can utilize formal and informal aquaculture training available through government agencies and private companies. Third, attending vocational, college, or degree programs in aquaculture is another effective method. The results showed that the majority of fish farmers have relatively long-standing experience in the aquaculture industry, with most having an average farming experience of between 11-15 years.

Involvement in aquaculture operations allows potential farmers to learn actual practices and managerial skills, thus gaining the experience needed to further develop their expertise in tilapia culture. Over the years, farmers may encounter setbacks and misjudgments in their tilapia farming. Any successes or failures they experience contribute to their knowledge and help them become better fishery managers or workers.

The significance of farming experience in tilapia production cannot be overemphasized. It determines farmers' ability to make effective farm management decisions, not only in adhering to agronomic practices but also in terms of input combination and resource allocation. Farming experience is expected to influence farm production efficiencies because of the accumulation of skills. The longer a person stays in a particular job or activity, the better their performance tends to be [28].

3.3 Technical Efficiency

3.3.1 Hypotheses testing

The sigma squared (σ^2) which indicates goodness of fit, was statistically significant at the 0% level, demonstrating the goodness of fit of the survey data with the model used and the accuracy of the specified coefficients. To test the null hypothesis that there was no significant technical inefficiency, and hence observed variations in technical efficiency (TE) estimates were simply random or systematic (H0 = 0), an estimated γ parameter, which measures the variability of the two sources of error, was statistically significant at 0% level. This implies that the variation of the total production among the different tilapia farms in was due to the differences in their production inefficiencies.

3.3.2 Technical efficiency analysis

The predicted technical efficiencies of all the surveyed farms ranged from 0.03 to 0.99, with a mean technical efficiency of 0.44. This suggests that, on average, the respondents were able to achieve 44% of potential output from a given mix of production inputs. The estimated technical efficiency for the tilapia farmers was 0.44, indicating that they could reach full technical efficiency by increasing their outputs by another 56% with the current level of technology and input levels. Individual efficiencies are shown in Fig 3.

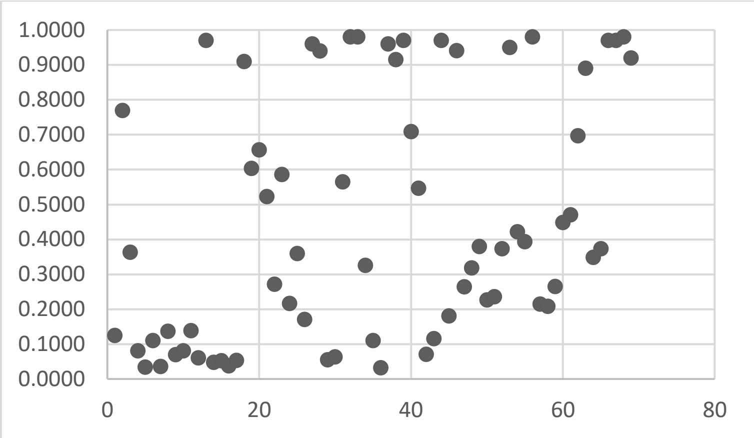

Fig. 3. Individual technical efficiencies of tilapia farmers

Table 6. Variables affecting production

Variables	Coefficients	*P* value
Area	3.9674e-01	0.033023*
Stocking rate	4.3798e-01	0.001048**
Labor	3.2799e-02	0.116387
Feeds	6.4259e-02	0.652366
Fuel	3.7646e-02	0.556944
Machineries	-6.6759e-03	0.868651
Medicine	-1.6534e-02	0.696190

*Note: Significance codes; P < .000 = '****', P < .001 = '***', P < .01 = '**', P < .05 = '*'*

Technical efficiency in production refers to the physical ratio of product output to factor input, where a higher ratio indicates greater technical efficiency [29]. This definition suggests that differences in technical efficiency exist between farms. The production function assumes technical efficiency, aiming for maximum output from a given level of input combination, thus representing a factor-product relationship. An essential assumption regarding efficiency is that farms operate on the outer bound production function, known as their efficiency frontier. When farms do not operate on this frontier, they are considered technically inefficient.

According to Heady (1960), improvement in technical efficiency can occur in three ways. Firstly, technical efficiency can be enhanced through improved production techniques, involving changes in factor proportions via factor substitution within a given technology, thus representing a shift along the production function. Secondly, technical efficiency can be improved through advancements in production technology, resulting in more output from the same number of resources or the same output from fewer resources. Thirdly, technical efficiency can be enhanced through improvements in both production techniques and technology.

The average production was estimated using the coefficients of the Cobb-Douglas production function. Only those observations with positive error terms were retained. These were then regressed against the same explanatory variables and the process repeated until the estimates were stable as shown in Table 6.

The coefficients for inputs, specifically area and stocking rate, were found to be significant ($P < .05$ and $P < .01$, respectively). The level of technical efficiency, representing the ratio of actual to potential output, was calculated for each farmer. Actual output refers to observed output, while potential output is the output from the frontier production function. Table 6 shows the positive and highly significant coefficients of the area and stocking rate variables, confirming the expected positive relationship between tilapia production output and these variables. This indicates that they are important factors in explaining changes in farmers' output. Essentially, the larger the focus pond/cage area and the greater the number of fingerlings used in production, the higher the yield.

The coefficient of Area (0.397) has a positive sign and is significant at ($P < .05$). This implies that a 1 percent increase in area would result in a 0.397% increase in fish production output. Further, the coefficient of stocking rate (0.438) was positive and significant ($P < .01$). This implies that 1% increase in the number of stocks would lead to a 0.438% increase in the fish production output. These results align with other studies where authors have found significant differences in technical efficiency between large and small culture systems [30-32]. The land area takes into account production inefficiencies arising from differences in economies of scale. It is expected that increased farm size diminishes the timeliness of input use, as well as the actual inputs available per hectare of the farm. The area of the focus pond/cage is a significant determinant of fish productivity, as it provides living space for the fishes. In the study areas, 66% of farmers owned pond/cage areas ranging from 0.1 to 2 hectares, while 34% of farmers had less than 2 hectares of pond/cage area. This clearly indicates the smaller size of the pond/cage available to farmers in the areas covered by this study.

Given the differences in efficiency levels among production units, it is pertinent to question why some producers can achieve relatively high efficiency while others are technically less efficient. Variation in technical efficiency may stem from managerial decisions and farm characteristics that influence the producer's ability to effectively utilize existing technology. A probit regression was conducted to assess the contribution of various factors to technical efficiency. Farms with technical efficiency below 50% were categorized as inefficient, while those above 50% were deemed efficient. The study used inefficiency as the dependent variable, and thus variables with a negative (positive) coefficient sign were shown to have a positive (negative) impact on technical efficiency, as indicated in Table 7.

The coefficient of farmers' access to government assistance/facilities was found to be negative and statistically significant ($P < .001$). This implies that farmers with access to government assistance/facilities are more technically efficient. The most efficient farmers have likely acquired skills over time through frequent contact with extension workers and attendance at government-initiated training programs. Fish farmers who have access to government facilities/training are more efficient, possibly because they can easily learn about new or improved technologies and have the opportunity to interact with other farmers during organized training programs. The Bureau of Fisheries and Aquatic Resources usually offers aquaculture trainings to interested farmers, covering aquaculture techniques and managerial guidelines. In addition to the knowledge gained from the training itself, farmers who attend and complete the course are often provided with initial startup materials such as fish fingerlings and feeds to help jump-start their aquaculture business.

The z-variable "use of Aerator" was found to have a negative coefficient and was statistically significant ($P < .05$). This indicates that farmers who use aerators on their aquaculture farms are considered more efficient compared to those who do not use aerators. This implies that a higher presence of aerators leads to a higher dissolved oxygen (DO) level in the water, resulting in increased productivity. Guided by this result, farmers can use this finding to improve their management strategies. They can consider actions to increase the DO level in the water, such as reducing pollutants near the cages or implementing mechanisms to enhance DO levels, such as adding aquatic plants for photosynthetic activity [33] or installing an aeration system.

According to Eze and Ajmal [34], DO plays a crucial role in the success of the fish production. DO levels can be a limiting factor that affects the growth and survival of fish stocks. Likewise, Low DO levels caused by increasing water temperature also affects the behavior and physiological changes of a fish [35]. They tend to eat less in an environment with low DO levels, leading to slow growth and, in some cases, mortality. Therefore, maintaining suitable DO levels in the water can be a contributing factor to the success of aquaculture ventures. Thus, increasing the level of DO through the installation of an aerator system can result in increased fish production. By ensuring adequate oxygenation of the water, fish are provided with optimal conditions for growth and development, ultimately leading to higher yields and improved profitability for aquaculture operations.

Further, the z-variable "Culture Method," where a dummy variable was used (1 for pond and 0 otherwise), was found to have a negative coefficient and was statistically significant ($P < 0.1$). This suggests that pond culture was more efficient in aquaculture activities and management compared to cage culture. This result is supported by the profit analysis conducted in this study. In the profit analysis, pond culture was found to be more profitable.

The difference in technical efficiency has another significant implication. The worst-performing farm, with a technical efficiency score of 3%, has the potential to increase their efficacy regarding input use up to 97% (thus reaching the optimal technical efficiency score of one) simply by sharing their own experiences and implementing the input management strategies of best-practice farms, as well as by receiving government support. Hence, the key to eliminating technical inefficiency in fish farming in the Philippines lies in the adoption of best farming practices and efficient input application management from farms that demonstrate high levels of efficiency. By learning from successful farms and receiving support from government initiatives, less efficient farms can significantly improve their technical efficiency and overall productivity.

3.3.3 Profit analysis

For the profit analysis, production costs are determined not only by the prices of inputs (feeds, fingerlings, fertilizer) but also by wage rates for labor in one tilapia culture cropping. The results showed that farmers venturing into tilapia farming in ponds, percentage-wise, are earning more compared to those practicing tilapia cage culture, with a profit margin of 50.10% compared to 16.49% for cage culture based on a single cropping. This indicates that, in terms of profitability, pond culture outperforms cage culture. The result of the study has already established the fact that pond farming is more profitable than cage farming (Fig 4).

Table 7. Factors affecting farmers' technical efficiency

Variables	Coefficients	*P* value
Age	2.9829e-02	0.047473*
Household Size	1.2186e-01	0.129808
Farm Experience	-3.6421e-02	0.101983
Years in School	6.8163e-02	0.078774
Access to Government Service /Facilities	-1.9435e+00	2.125e-06***
Aeration	-1.6622e+00	0.033195*
Water Source	-1.8943e-01	0.600482
Gender	-8.7578e-02	0.827358
Culture Method	-1.4300e+00	0.005770**

*Note: Significance codes; P < .000 = '****', P < .001 = '***', P < .01 = '**', P < .05 = '*'*

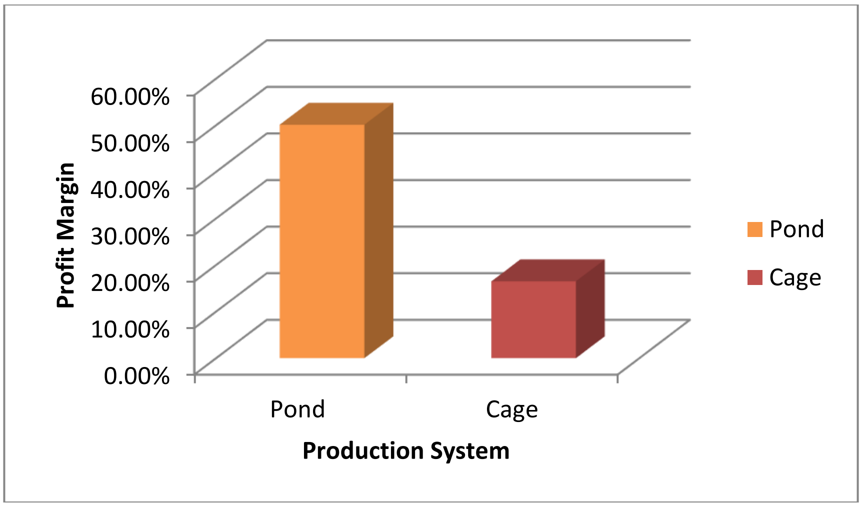

Fig. 4. Comparison of profit between pond and cage aquaculture

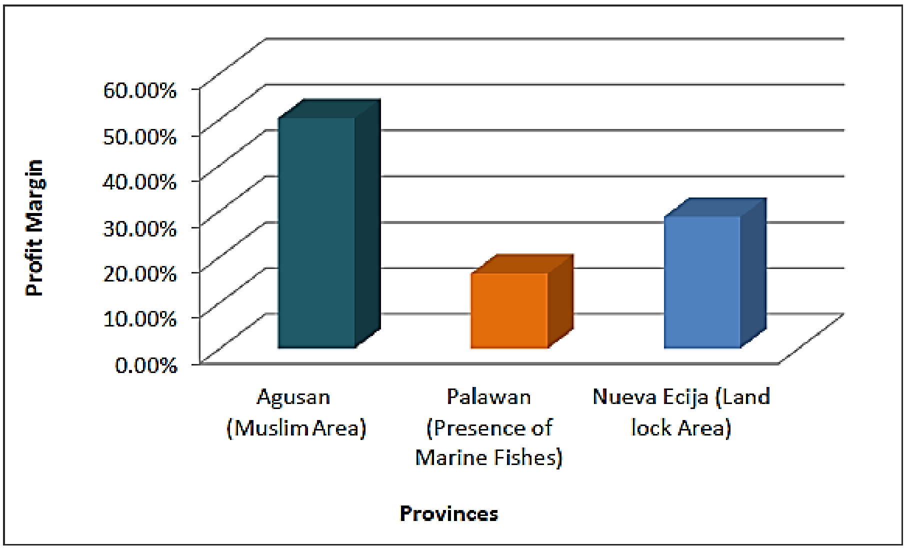

Fig. 5. Profit analysis comparing the percentage profit of three provinces with different socio-demographics

In general, profitability, in its most general interpretation, measures whether revenue generated by the business exceeds total costs incurred by the business [36]. Determination of profitability of any business enterprise always involves consideration of the cost structure as well as the revenue accruable in business. To continue its aquaculture activities, the farm business must be able to sell fish at a price that is greater than its break-even price above variable costs.

Another analysis was conducted to compare pond profitability in three different scenarios: a province with mostly Muslim population (represented by Agusan), a province with access to both marine capture aquatic organisms and fishes from aquaculture (represented by Palawan), and a landlocked province with very limited supply of aquatic marine organisms and mostly dependent on aquaculture (represented by Nueva Ecija).

The results showed that tilapia farmers in Agusan have the highest profit compared to the other provinces. This is due to the fact that Muslims do not consume meat in their daily diet, narrowing the choice of protein sources for the consuming public to chicken and fish. Consumers tend to buy fish rather than meat even if the price for tilapia is higher in this area compared to other provinces. The average price of tilapia in the Agusan area is 160/kg, while in other provinces, the average price ranges from 100-120/kg.

In the case of Palawan, tilapia is sold at a lower price compared to the price in Agusan because consumers have many choices in terms of fish available in the market. The abundant supply of marine fishes in the market limits the price of tilapia from surging. Thus, profit from tilapia in Palawan has recorded the lowest among the three provinces.

3.3.4 Prices of tilapia

The recorded difference in tilapia prices observed in the study is presented in Table 8. Farm gate price refers to the price for the sale of farm produce directly from the producer, while the market price is the price of a commodity (tilapia) when sold in a given market. Market price is also defined as the current price at which a commodity can be bought or sold. Price is the value that is assigned to a product or service and is the result of a complex set of calculations, research, understanding, and risk-taking ability [37].

3.3.5 Problems and constrains in tilapia farming

The survey revealed several constraints hindering the efficient production of tilapia, as shown in Table 9. The two most serious problems in the study area were poor water quality and the high cost of fish feeds. Eighty-eight percent of respondents opined that poor water quality was a major issue during the culture period and when they wanted to restock

Table 8. Recorded prices of tilapia during the study

Size	Average Price (Pesos)	Remarks
200g and below	80	Farm gate price
	89	Market price
200g-300g	90	Farm gate price
	105	Market price
300g-400g	100	Farm gate price
	110	Market price
400g-500g	115	Farm gate price
	135	Market price
500g and above	150	Market price

Table 9. Problem and constrains faced by the tilapia farmers in the study area

Variables	Frequency	Percentage (%)
Poor water Quality	62	88.57
High Cost of Feeds	60	85.71
Predators (eel, birds, snake, etc.)	48	68.57
Unstable supply of stocks	45	64.29
Marketing Problem	9	12.86
Poaching	12	17.14
Inefficiency of the laborers	5	7.14

Note: n= 75

their ponds or cages after each production cycle. Poor water quality characteristics may include pollution, turbidity, and low dissolved oxygen levels, all of which contribute to low production in their fish farms. Additionally, eighty-five percent of the farmers complained about the high cost of feeds, supporting the findings of Okwu and Achenje [38] Other problems mentioned included predators, the unstable supply of stocks, and poaching.

4. CONCLUSION

Despite continuous growth in tilapia aquaculture in the Philippines, the potential for expansion in tilapia farming is still far from exhausted. The study observed wide variations in the level of technical efficiency scores among the sample fish farms. More than 62% of the sample farms are operating below the average level of technical efficiency, which may be due to mismanagement regarding input mix. Furthermore, results indicate that the use of aerators, the application of improved culture methods, and increased access to government assistance and facilities—such as training, inputs, and other extension services—can reduce inefficiency among tilapia farmers in the Philippines. Hence, interventions should focus on the application and adoption of advanced culture technologies, increasing farmers' access to government assistance, and providing necessary inputs, services, and facilities to increase production and income of fish farmers towards the achievement of sustainability and fish sufficiency in the country.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. SEAFDEC. Fishery Statistical Bulletin of Southeast Asia 2020; 2023.
Available: https://repository.seafdec.org/handle/20.500.12066/7172
Accessed 28 April 2024.

2. Demavivas K. 4 ways to ensure the future of aquaculture is sustainable; 2023. Available:https://www.weforum.org/agenda/2023/03/4-ways-to-ensure-the-future-of-aquaculture-is-sustainable/ Accessed 12 May 2024.
3. Cabral R, Geronimo R, Mamauag A S, Silva J, Mancao R, Atrigenio M. Ensuring Aquatic Food Security in the Philippines. The Philippine Journal of Fisheries. 2023;298–313. DOI:10.31398/tpjf/30.2.2022-0031
4. Farrell MJ. The Measurement of Productive Efficiency. Journal of the Royal Statistical Society: Series A (General). 1957;120:253-281. DOI: https://doi.org/10.2307/2343100
5. Fried HO, Lovell CK, Schmidt SS. The measurement of productive efficiency and productivity growth. Oxford University Press; 2008.
6. Rocha LA, Cárdenas LQ, Oliveira FSD, Lopes FD, Fernandes KC. The impact of R&D investments on performance of firms in different degrees of proximity to the technological frontier. Economics bulletin. Nashville. 2018;38:1156-1170. DOI: 10.25115/eea.v37i3.2794
7. Li D, Hao Y, Duan Y. Nonintrusive methods for biomass estimation in aquaculture with emphasis on fish: A review. Reviews in Aquaculture. 2020;12 (3):1390-1411. DOI: https://doi.org/10.1111/raq.12388
8. Alagaraja K. Assessment of fish production in aquaculture. Aquaculture Productivity. 1991;491-500.
9. Ahaz I. Population dynamics and stock assessment of Hilsa Shad, *Tenualosa ilisha* in Iran (Khuzestan Province). Journal of Fisheries and Aquatic Science. 2011; 6(2):151-160. DOI: 10.3923/jfas.2011.151.160
10. Alatorre-Jácome O, Rico-García E, Soto-Zarazúa GM, García-Trejo F, Herrera-Ruiz G. A thermosolar nursery for tilapia (*Oreochromis niloticus* L.). Scientific Research and Essays. 2011;6(21):4619-4626. DOI: 10.5897/SRE11.943
11. Kumbhakar SC, Lovell CK. Stochastic frontier analysis. Cambridge university press; 2003.
12. Masudkar DD, Kamble VB, Anarase MS. Socio-economic status of the farmers in adopted village. Journal of Pharmacognosy and Phytochemistry. 2017;6:1117-1119.
13. Dey MM. Strategies and options for increasing and sustaining fisheries and aquaculture production to benefit poorer households in Asia WorldFish. 2008;1823.
14. Prodhan MMH, Khan MA, Palash MS, Rahman MT. Nature, extent, and causes of post-harvest losses at fisher and farmer level: An in-depth study. Aquaculture. 2022;550:737856. DOI: 10.1016/j.aquaculture.2021.737856
15. Bindlish V, Evenson RE. Evaluation of the Performance of T & V Extension in Kenya (Vol. 23). Washington, DC: World Bank; 1993.
16. Lockheed ME, Jamison T, Lau LJ. Farmer education and farm efficiency: A survey. Economic development and cultural change. 1980;29(1):37-76. DOI: 10.1086/451231
17. Moock PR. The efficiency of women as farm managers: Kenya. American Journal of Agricultural Economics. 1976;58(5):831-835. DOI: 10.2307/1239979
18. Aigner D, Lovell CK, Schmidt P. Formulation and estimation of stochastic frontier production function models. Journal of Econometrics. 1977;6 (1):21-37. DOI:https://doi.org/10.1016/0304-4076(77)90052-5
19. Meeusen W, van den Broeck J. Technical efficiency and dimension of the firm: Some results on the use of frontier production functions. Empirical economics. 1977;2:109-122.
20. John OA, Olawunmi MY, Taofeek BA, Chidima NOL, Olufunso E. Gender analysis of culture fish enterprises in Epe local area of Lagos state, Nigeria. International Journal of Sciences: Basic and Applied Research. 2016;26:292-303.
21. Dyche LL. Ponds, pond fish, and pond fish culture. Kansas State Printing Office. 1914;1.
22. Athirah A, Mustafa A, Ratnawati E, Asaf R. Correlation between socio-demographic characteristics and adoption rate of good aquaculture practices in traditional technology-based fishpond in Pinrang Regency. In IOP Conference Series: Earth and Environmental Science. IOP Publishing. 2020;564(1):012069 DOI: 10.1088/1755-1315/564/1/012069

23. Alam MF, Khan MA, Huq AA. Technical efficiency in tilapia farming of Bangladesh: a stochastic frontier production approach. Aquaculture International. 2012; 20:619-634.
DOI: 10.1007/s10499-011-9491-3
24. Kusakabe K, Thongprasert S. Women and men in small-scale fisheries and aquaculture in Asia – Barriers, constraints and opportunities towards equality and secure livelihoods. Bangkok, FAO; 2022.
Available:https://doi.org/10.4060/cb9527en
25. FAO. The State of World Fisheries and Aquaculture. Contributing to food security and nutrition for all. Rome. 2016;200.
26. Obasi PC, Henri-Ukoha A, Ukewuihe IS, Chidiebere-Mark NM. Factors Affecting Agricultural Productivity Among Arable Crop Farmers in Imo State, Nigeria. Journal of Experimental Agriculture International. 2013;3(2):443-54.
Available:https://doi.org/10.9734/AJEA/2013/2030.
27. Allen JP, Van der Velden, RKW. Skills for the 21st century: Implications for education; 2012.
28. Fisher CD. Happiness at work. International Journal of Management Reviews. 2010;12(4);384-412.
DOI: 10.1111/j.1468-2370.2009.00270.x
29. Shanmugam KR, Venkataramani A. Technical efficiency in agricultural production and its determinants: An exploratory study at the district level. Indian Journal of Agricultural Economics. 2006;61(2).
30. Dey MM, Paraguas FJ, Bimbao GB, Regaspi PB. Technical efficiency of tilapia growout pond operations in the Philippines. Aquaculture Economics & Management. 2000;4(1-2):33-47.
DOI: 10.1080/13657300009380259
31. Irz X, Mckenzie V. Profitability and technical efficiency of aquaculture systems in Pampanga, Philippines. Aquaculture Economics & Management. 2003;7(3-4): 195-211.
DOI: 10.1080/13657300309380340
32. Kumar P, Rosegrant MW. Productivity and sources of growth for rice in India. Economic and political weekly. 1994; A183-A188.
Available:http://www.jstor.org/stable/4402195
33. Macaraeg NA, Saturno JO. Rhizofiltration potential of floating aquatic macrophytes (FAMs) in Nile Tilapia (*Oreochromis niloticus* L.) tanks. International Journal of Fisheries and Aquatic Studies. 2023;11(3):35-39.
DOI:https://doi.org/10.22271/fish.2023.v11.i3a.2805
34. Eze E, Ajmal T. Dissolved oxygen forecasting in aquaculture: A hybrid model approach. Applied Sciences. 2020;10(20): 7079.
DOI: 10.20944/preprints202009.0518.v1
35. Macaraeg NA, Vera Cruz EM, Templonuevo RMC. Influence of Different Temperatures and Sexes on the Survival and Stress Responses of Nile Tilapia (*Oreochromis niloticus* L.). Asian J. Fish. Aqu. Res. 2023;23(1):14-23.
DOI: 10.9734/AJFAR/2023/v23i1592
36. Achim M, Borlea S. Business Performances: Between Profitability, Return and Growth. Annals of University of Craiova—Economic Sciences Series. 2008;2;1-12.
37. Anderson JC, Wynstra F. Purchasing higher-value, higher-price offerings in business markets. Journal of Business-to-Business Marketing. 2010;17(1): 29-61.
DOI: 10.1080/10517120903000363
38. Okwu, OJ, Acheneje S. Socio-economic analysis of fish farming in Makurdi Local Government area, Benue State, Nigeria. European Journal of Social Sciences. 2011;23(4):508-519.

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