CEM WORKING PAPER SERIES

TECHNICAL EFFICIENCY AND PROFITABILITY OF TILAPIA AND MILKFISH GROWOUT CAGE OPERATIONS IN TAAL LAKE, TALISAY, BATANGAS, PHILIPPINES

by

Reynaldo L. Tan, Yolanda T. Garcia and Isabel Mildred A. Tan

Working Paper No. 2009-12

College of Economics and Management
University of the Philippines Los Baños
College, Laguna
Philippines
January 2009

TECHNICAL EFFICIENCY AND PROFITABILITY OF TILAPIA AND MILKFISH GROWOUT CAGE OPERATIONS IN TAAL LAKE, TALISAY, BATANGAS, PHILIPPINES

Reynaldo L. Tan, Yolanda T. Garcia and Isabel Mildred A. Tan

ABSTRACT

This study was conducted to assess the relative profitability and technical efficiency of tilapia and milkfish cage operations in Taal Lake, Talisay, Batangas, Philippines. A complete enumeration of the 23 milkfish cage operators and a sample of 40 tilapia cage operators were interviewed in the study. Cost and return analysis, measurement of technical efficiency using the translog frontier production function and identification of the sources of inefficiency were conducted to analyze the data. Results showed that the average technical efficiency and profitability of tilapia production were both higher than that of the milkfish culture. Analysis of the sources of inefficiency for milkfish and tilapia cage operation indicated that operators can further increase their productivity through proper stocking density and feeding rate. One of the key recommendations of the study points to the reduction of feeding rate presently employed by milkfish operators to raise production efficiency. On the other hand, sourcing for better quality fingerlings with lower mortality rate is seen as an effective way of increasing technical efficiency among tilapia operators.

Keywords: Milkfish, tilapia, profitability, technical efficiency, translog production function

INTRODUCTION

Talisay is a coastal municipality along Taal Lake in the province of Batangas and is noted for its cage production of tilapia, popularly known as *tilapiang Talisay*. In recent years, many tilapia cage operators have shifted to milkfish operation, which has become a popular livelihood in the area. Tilapia and milkfish are the top aquaculture species grown in the country contributing about 29% and 53% to total production, respectively.

In the neighboring provinces of Batangas, e.g. Laguna, Quezon, Cavite and key cities in Metro Manila, when consumers purchase tilapia, they often look for '*tilapiang Talisay*' (which literally means tilapia from Talisay). *Tilapiang Talisay* has gained a distinct quality trademark and is highly preferred by consumers due to its taste and flesh quality. In many local markets, sellers of tilapia call the attention of buyers by yelling '*tilapiang Talisay*.' The distinction affords the consumer an assurance that they will be buying the best tasting tilapia. *Tilapiang Talisay* has been so popular that even in the domains of other tilapia producing areas such as the seven lakes of San Pablo City and Laguna de Bay (the largest lake in the Philippines with an area of 90,000 hectares), *tilapiang Talisay* dominates the market.

Talisay is one of the 11 municipalities around Taal Lake, the third largest lake in the Philippines with an area of 26,750 hectares. It is considered as the second most important lake next to Laguna de Bay in terms of fish culture and concentration. Three of the 21 barangays of Talisay are coastal barangays, namely: Aya, Sampaloc and Quiling, which are situated at the northern part of lake.

Tilapia culture in Taal Lake has its beginning from the introduction of the species and cage aquaculture technology by the Bureau of Fisheries and Aquatic Resources (BFAR) in the 1970s. However, it was only from early 1990s when a tremendous growth in cage culture of tilapia came about.

Milkfish farming is relatively new in Talisay which started only in 1999, particularly in the coastal barangay of Sampaloc. Based on key informant interviews in the area, milkfish aquaculture started in Taal Lake when a strong typhoon destroyed most of the milkfish ponds in Bulacan (a major milkfish producing province in the country) causing the owners to look for alternate sites for their operation. Milkfish cage culture proved to be successful in Taal Lake which eventually enticed many local tilapia cage operators to shift to milkfish production. New investors from nearby municipalities have also entered into the business making milkfish cage culture also an important economic activity in Taal Lake.

This study was conducted to assess the efficiency and profitability of tilapia and milkfish cage productions in Taal Lake, Talisay, Batangas. The paper is divided into three major sections. Section 2 discusses the analytical models used in the study namely: a) cost and return analysis; b) frontier production function model; c) technical efficiency estimation and d) multivariate analysis of the determinants of technical inefficiency. Section 3 is focused on the results of the study which is divided into the following subsections: a) socio-economic profiles of tilapia and milkfish cage operations; b) comparative profitability of each culture system; and c) discussion of the estimates of technical efficiency and the respective key factors (socio-economic and bio-physical) that affect the farm-level efficiency of the operators. The final section is devoted to conclusion and recommendation.

OBJECTIVES

The general objective of the study is to assess the relative profitability and technical efficiency of tilapia and milkfish cage operation in Taal Lake, Talisay, Batangas. The paper has four specific objectives, namely:

1. To conduct comparative cost and return analysis of tilapia and milkfish cage culture in the study area;
2. To compare the input-output relationships of the two culture systems;
3. To measure the technical efficiency of the two systems and identify the factors that affect these; and

4. To formulate recommendations towards improving efficiency and profitability of the respective culture systems.

METHODOLOGY

Data Source

This study made use of data on tilapia and milkfish cage culture operations in Talisay which were collected in 2002 under the BFAR-UPLB-WorldFish Center project entitled "Strategies and Options for Sustaining Fisheries and Aquaculture Production to Benefit Poor Households in Asia" with funding from the Asian Development Bank (ADB).

The data on milkfish cage culture were gathered through a complete enumeration of all milkfish farms in Talisay. During data collection, a population of 24 milkfish farmers was identified with 72 cages situated in Barangay Sampaloc and two cages in Barangay Quiling. Incidentally, one farmer had just started operation then (hence no completed culture cycle yet) and was excluded from the analysis. The data provided by milkfish operators were averages of inputs and outputs based from their multiple cage operation.

On the other hand, the data on tilapia cage culture were taken from a sample of 40 farmers in the three coastal barangays of Talisay, namely: Aya, Quiling, and Sampaloc. A total of 232 cages were operated by the 40 farmers with an average of 2.5 cages per farm. Knowledge and experience of the cage operation were major considerations in the selection of the respondents which led to the inclusion of caretakers who were in charge of the operation, in the case of farms with absentee owner-operators. A total of 26 owner-operators and 14 caretakers were interviewed for this purpose. Data on tilapia cage operation were farm averages as well.

The survey sites are shown in Figure 1.

Cost and Return Analysis

The profitability of each culture system can be assessed by employing cost and return analysis of individual cage operators per culture cycle. The average net return is then derived based on the mean of net incomes gained by all operators included in the study under each culture system. To enhance comparability, average net returns are expressed on a per m^2 basis. However, comparison can be constrained by significant differences in the culture lengths and operating costs of the two production systems. In such cases, more relevant comparison can be achieved by using a constant time period sufficient to complete (unequal) culture cycles while taking into account the relative values of operating costs incurred per cycle.

Technical Efficiency Analysis

Technical efficiency (TE) reflects the ability of a farmer to obtain the highest possible output from a given set of inputs and available technology. Conceptually, TE measures the difference between the yields of average farmers vs. the best farmers exhibiting the potential/maximum output of a given production system. Mathematically, TE is the ratio of the operator's actual output (Y) to the technical maximum possible output (Y*) given a fixed set of resources and technology. In many empirical studies, technical inefficiency (TI), instead of technical efficiency (TE), is often measured and represented simply by the following formula: TI = 1-TE.

Measuring the technical efficiency or inefficiency of milkfish and tilapia cage operators can provide key information in formulating alternative options to improve aquaculture productivity of farmers in a specific locality. Generally, operators are either efficient or inefficient (at varying degrees) in their production operation. Consequently, these two scenarios require entirely different strategies in improving or increasing productivity. For example, for farmers who are currently inefficient in their production system, the strategy to improve their productivity is to focus on the factors that can increase efficiency. Hence, factors that contribute directly to inefficiency must be identified in order to address them. On the other hand, if operators are already efficient in their production system, then the way to enhance their productivity is to introduce or shift to a new technology that will increase output level.

The procedure for measuring technical efficiency/inefficiency entails several options in estimating the underlying production function that defines the input-output relationship of the farmer. Among the existing approaches, the stochastic frontier model had been one of the most popular and appropriate in assessing farm efficiencies in Asian aquaculture (Dey et. al. 2005; Bimbao et al., 2000; Sharma & Leung, 2000a, 2000b; Irz & McKenzie, 2003).

The technical efficiency model used in this study is based on the works of Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977) which specify the production function as follows:

$$Y_i = f(X_i; \beta) \exp(V_i - U_i)$$

where: Y_i is the output of the i^{th} farm ($i = 1, 2, 3, \ldots, n$);

X_i is a $1 \times k$ vector of input quantities applied by the i^{th} farm;

β is a $k \times 1$ vector of model parameters to be estimated;

U_i is a non-negative random error term associated with technical inefficiency in production;

V_i is a random error term assumed to be normally distributed with mean zero and variance σ_v^2, i.e., $V_i \sim N(0, \sigma_v^2)$ and is independent of U_i.

Note that the technical efficiency model includes two types of error terms, i.e., V_i which accounts for the usual random effects in the model while U_i represents the technical inefficiency in production. Following Battese and Coelli (1995), the error term U_i is assumed to be independently distributed and has a half-normal distribution with truncation at zero, i.e., $U_i \sim |N(\mu_i, \sigma_u^2)|$.[1]

The farm-specific frontier production function (Y*) representing the maximum possible output can be expressed as:

$$Y_i^* = f(X_i; \beta) \exp(U_i)$$

The technical efficiency of individual farmer can be predicted based on the conditional expectation of exp(-U_i). The level of efficiency depends on the value of U_i and is interpreted as follows: a) if $U_i > 0$, then production lies below the frontier function and the farm is considered technically inefficient; and b) if $U_i = 0$, then production lies on the frontier function and the farm is deemed technically efficient. Figure 2 shows the graphical illustration of technical inefficiency given the yield difference between the "best" and "average" farmers as represented by the frontier and mean production functions, respectively. Specifically, technical efficiency (TE_i) of the i^{th} farm is derived as follows:

$$TE_i = \frac{Y_i}{Y_i^*} = \exp(-U_i)$$

The variance of the model (σ^2) can be expressed as the sum of the variance parameters σ_v^2 and σ_u^2, i.e.,

$$\sigma^2 = \sigma_v^2 + \sigma_u^2$$

$$\gamma = \sigma_u^2 / \sigma^2$$

The value of gamma (γ) ranges from 0 to 1 which indicates the possible source of deviation of a

[1] The choice for this assumption by most researchers is based on the ease of estimation and interpretation, and the fact that estimates of technical efficiency are found to be similar or have negligible differences among various distributions commonly used such as half-normal, truncated-normal and exponential functions [(Parikh *et al*. 1995; Greene 1990), as cited in Dey *et al*. 2000].

given production level from the frontier production function. Specifically, a value of γ equal to 1 implies that the production deviations from the frontier function are due entirely on technical inefficiency (Coelli *et al.* 1998).

To investigate the possible sources of technical inefficiency, TE can then be expressed as the function $TE_i = \delta Z_i$ where Z_i is a $1 \times m$ vector of farm-specific variables that may help explain the observed technical inefficiency among farmers while δ is an $m \times 1$ vector of parameters to be estimated.

Empirical Models

To establish the specific relationship between output and inputs, an empirical production function must first be specified which commonly take the forms of the Cobb-Douglas (CD) or the transcendental logarithmic (translog) functions. Despite the restrictive nature of the CD function, i.e., constant returns to scale, Dey et al (2005) have shown that the CD specification can better capture the production behavior of freshwater aquaculture. Incidentally, the translog production function reduces to CD specification when all the coefficients associated with the second-order relationships of inputs or interaction terms of the function are equal to zero. However, when there are significant interactions among production inputs, the translog function can be more advantageous than CD in capturing the production process.

To determine the factors that explain farmer's efficiency, either the TE or TI can be expressed as a function of the various farm-specific factors that are hypothesized to affect these. Hence, a regression function for technical efficiency/inefficiency is specified as follows:

TE/TI = f(farm-specific factors like water quality, depth etc.; and farmer-
specific factors, like age, education, and training, etc.)

Two approaches can be used to estimate this regression model. One is to estimate the TE/TI measure in the first stage and then run the regression model in the second stage. The second approach is to estimate the frontier production function and efficiency regression model simultaneously. The first approach using the two-stage estimation procedure[2] has long been recognized to violate the assumption regarding the independence of inefficiency effects in the two estimation stages (Dey et. al, 2000). On the other hand, the second approach using the system model boasts of generating parameter estimates that are statistically efficient. This study employed the second approach and obtained the maximum-likelihood estimates (MLEs) of the frontier production function and the parameters of the technical inefficiency regression simultaneously using the FRONTIER Version 4.1 software (Coelli, 1994).

RESULTS AND DISCUSSION

Socio-Demographic Characteristics of Milkfish and Tilapia Cage Operators

The general profile of the milkfish and tilapia cage operators is shown in Table 1.

Tenure status

Cage operators consisted of respondents who were directly involved and knowledgeable of the production operations. Consequently, the tenure status was categorized into owner-operator and caretaker. The caretaker category refers to a system with either a hired labor or tenant taking care of the operation while the owners' role was basically limited to investment or capital provider.

All the 23 milkfish cage operators interviewed were found to be owner-operators. On the other hand, among the 40 tilapia cage operators, 65% were owner-operators while 35% were caretakers.

[2] The first stage estimates the stochastic frontiers and farm-level efficiencies, and second stage regresses the predicted efficiencies upon farm-specific variables.

Age, sex, household size and marital status

In general, milkfish cage operators were younger and have smaller household size than the tilapia cage operators. The average age of the milkfish cage operators was 32 years old and has an average of 3 household members. Majority of the farmers (67%) were married.

In the case of the 26 tilapia cage owner-operators, the average age was 47 years old with an average household size of four. Sixteen (62%) of them were married and three (1%) were widows who continued tilapia cage operation after their husbands died. On the other hand, the 14 caretakers were relatively younger, with average age of 34 years old, and having the same household size of 4 members. Majority of the caretakers (71%) were married.

Educational background

Educational attainment was categorized into elementary, high school and college levels. Of the 23 milkfish operators, fourteen (61%) of them reached high school level, four (17%) finished elementary level and five (22%) reached college level, one was a degree holder.

In the case of tilapia cage operators, 12 (46%) of the 26 owner operators reached high school, seven (27%) finished elementary and also seven (27%) reached college level, of which three were college degree holders. On the other hand, nine of the 14 caretakers (64%) reached high school level, three (21%) reached college while two just reached elementary level.

Years of experience of cage operators

Milkfish cage operation was relatively new in the area at the time of the survey, hence the years of experience of the operators ranged only from less than a year to 2.5 years with an average of 1.2 years (equivalent to two culture cycles). Of the 23 milkfish cage operators, 13 (57%) were formerly tilapia cage operators and 10 (43%) were new operators in the area.

The average years of experience in fishcage operation of all tilapia cage operators is 4.6 years. However, the average for owner-operators was more than twice (5.7 years) that of the caretakers (2.5 years). The higher average of owner-operators was basically pulled up by the relatively longer years of experience of four owner-operators registering 12, 18, 20 and 30 years, respectively.

Production Practices of the Milkfish and Tilapia Operators

Table 2 shows the comparison of general production practices of the milkfish and tilapia cage operators.

General characteristics of farm structures

By Municipal Ordinance 01-96 in Talisay, Batangas, all cages must be of size 100 m^2 (10m×10m). Hence, all cages are of uniform size by surface area. However, the cage depths differed among milkfish and tilapia cage operators. The depth of milkfish cages ranged from 6.5 m to 8 m, with an average depth of 7.5 m. while that of tilapia cages ranged from 5 m to 10 m, with an average depth of 7 m. Cage depth is also affected by the depth of the lake where the cages are located.

The average total farm size of the milkfish cage operators was 330 m^2 (or 746 m^3). Given the uniform area of each cage, this is equivalent to about 3 units of cage holdings. Cage ownership actually ranged from 1 unit to 11 units. About 48% of the milkfish operators owned at most 2 units. In the case of tilapia cage operators, the average farm size was 577 m^2 (702 m3) an equivalent average cage holding of 6 cages per operator. However, almost half of the operators owned at most 3 cages.

General stocking practices

Stocking density of tilapia fingerlings ($56.2/m^3$) was 4.8 times higher than that of milkfish culture ($11.68/m^3$). Note that the standard deviation of stocking density in tilapia production (23.03/m3) was similarly higher by 5.15 times compared to milkfish culture ($4.47/m^3$). This indicates the high variability in production intensity that tilapia farmers were practicing compared to milkfish farmers.

Stocking of fingerlings is often done in two ways: a) direct stocking for bigger fingerlings where these are released directly into the grow-out cages and b) indirect stocking for smaller fingerlings which are initially reared in *hapa* (small mesh-size nets inside the grow-out cages) for a few weeks before they are released for grow-out culture to avoid fish escapes.

All the milkfish farmers practiced indirect stocking. In the case of tilapia farmers, 50% of the operators practiced direct stocking while the other half practiced indirect stocking. The main reason provided by cage operators who practiced indirect stocking was to improve the survival of the fingerlings through better acclimatization.

General feeding practices

About 14 different commercial fish feeds were used by the milkfish and tilapia cage operators in Talisay. Availability of supply, price and quality were the main consideration for the choice of the feeds. Often, cage operators would conduct feed trials and verification in their own farms when choosing feed brands.

Contrary to the case of stocking density, higher feeding rate was found to be practiced by milkfish operators as compared to tilapia operators. Feed application in milkfish culture (1.73 kg $/m^3$/month) was 4.3 times higher than in tilapia culture (0.41 kg/m^3/month) over relatively same length of culture period (5.8 and 5.1 months, respectively).

The broadcast method of feed application was generally adopted by both milkfish and tilapia cage operators. Moreover, majority applied feeds three times a day for both milkfish (91%) and tilapia (83%) cage operators.

General harvesting practices

Based on the average culture lengths, two culture cycles can be completed per year and consequently, two harvests can be carried out for both milkfish and tilapia cage culture.

The average production of milkfish per culture cycle was 2.68 tons per cage (3.61 kg/m^3), about two times higher than the average production of tilapia of 1.42 tons per cage (2 kg/m^3).

Costs and Returns of Milkfish and Tilapia Operations

Table 3 shows the comparative costs and returns of milkfish and tilapia cage operations in Talisay and their respective profitability. On the average, the gross return and costs of per cage and per m^3 operation for one culture cycle were respectively much larger for milkfish than in tilapia culture. Gross return of milkfish per cage (Php184,920) was 2.41 times larger than tilapia (Php73,840). This was attributed basically on the higher average yield (3.61 kg/m^3) and higher price (Php69/kg) of milkfish compared to tilapia, i.e., 2 kg/m^3 and Php52/kg, respectively.

The cost of operation of milkfish was 3.8 times higher than tilapia. This was basically attributed to the high feeding rate in milkfish production. Specifically, in milkfish cage operation, feeds and fingerlings comprised 75.3% and 15.3% of total cost, respectively. In the case of tilapia, the share of feeds was only 54.6% which was lower than in milkfish culture, but the share of fingerling cost was much larger (39.6%). In general, the share of the cost of feeds is higher than the cost of fingerlings in both culture systems.

The net income of tilapia culture per cage was Php28,743 which was two times larger than from milkfish culture (Php14,329). On a per m^3 basis, the net incomes from tilapia and milkfish operations were Php40.94 and Php19.20, respectively. Based on this cost and return analysis, tilapia appeared to offer better income option for cage operators than milkfish. Moreover, milkfish culture requires much higher capital outlays particularly on feeds and fingerlings costs. Total operating costs for milkfish was 3.8 times higher than tilapia. Hence, this raises an issue on whether the shift of some tilapia farmers to milkfish operation was justifiable. Given such considerations, there must be some incidental factors that can rationalize the shift to milkfish production. Some of these reasons were identified and expounded in the succeeding section.

Technical Efficiency Analysis

Milkfish Cage Operation

A Cobb-Douglas (CD) specification of the frontier production function was initially estimated using the Frontier Version 4.1 software. Two sets of frontier production function were specified. On the one hand, yield was specified as a function of fingerlings stocked per cage, feed application over one culture cycle, hired labor expenses for stocking and harvesting activities and capital investment measured in terms of depreciation of cage, boats, rafts and other fixed assets per culture cycle. On the other hand, all these variables were specified/standardized on a per m^3 basis. The main purpose is to check the effect of varying depths which make the effective cage volumes different since all cages have same or standard area of 100 m^2. In both models, the measured technical inefficiency[3] was specified as a function of culture period, operators' age, education, household size, years in cage culture business, farm size, depth of cage, and the four input variables in the production function, with the four input variables

[3] Frontier Version 4.1 estimates the per farm technical inefficiency and regresses it on the specified factors included in the model. The program also provides the mean and individual technical efficiency index for all observations (farms/operators) included in the data set.

expressed on a per m^3 units in the second model. Based on the results, the CD specification did not adequately capture the production behavior of the milkfish cage operation in Talisay. Hence, a translog specification of the frontier production function was then estimated which proved to yield better results due to the significance of the interaction terms. However, the per cage (expressed on a per m^2 units) gave better results than the model on a per m^3 units. Moreover, the differences in the estimated technical efficiencies between cages of different depths turned out to be insignificant. This was further supported by the insignificance of the depth of cage as a determinant of technical efficiency.

Following Dey et. al (2000), the translog model was specified as follows:

$$LnYi = \beta_0 + \sum_{j=1}^{4} \beta_j Ln(X_{ij}) + \sum_{j=1}^{4} \sum_{k=1}^{4} \beta_{jk} Ln(X_{ij}) Ln(X_{ik}) + V_i - U_i$$

where:

Ln Y	-	observed farm yield (kg/cage)
Ln X_1	-	stocking density (no. of fingerlings/cage)
Ln X_2	-	feeding rate (feeds applied in kg/cage/culture length)
Ln X_3	-	hired labor (Php/culture length)
Ln X_4	-	capital (depreciation value of fixed assets over culture length)
Ln X_5	-	$LnX_1 \times LnX_2$
Ln X_6	-	$LnX_1 \times LnX_3$
Ln X_7	-	$LnX_2 \times LnX_3$
Ln X_8	-	$LnX_1 \times LnX_4$
Ln X_9	-	$LnX_3 \times LnX_4$
Ln X_{10}	-	$LnX_2 \times LnX_4$
subscript i	-	refers to i^{th} observation in the sample
Ln	-	represents natural logarithm

Consequently, the farm-specific technical inefficiency (TI) model is specified as follows:

$$TI_i = \delta_o + \sum_{j=i}^{11} \delta_j Z_{ij}$$

where:

Z_1	-	culture period (months)
Z_2	-	operators' age (years)
Z_3	-	operators' educational level (years)
Z_4	-	years in aquaculture business
Z_5	-	depth of cage (meters)
Z_6	-	household size (number of members)

Z_7	-	farm area (m^2)
Z_8	-	stocking density (no. of fish/cage)
Z_9	-	feeding rate (feeds applied/cage/culture length)
Z_{10}	-	hired labor measured in terms of payment for stocking and harvesting activities (Php/culture length)
Z_{11}	-	capital (depreciation value of fixed assets over culture length)

The estimated parameters of the translog frontier production function and the determinants of the technical inefficiency models for milkfish operation are presented in Table 4. Expectedly, the parameters of stocking density, feed rate, labor and capital were found to be highly significant. However, feeding rate showed a negative sign indicating that the level of feed application was contributing negatively to output. This suggests that the present level of feed application of the operators may be excessive thus leading to built-up of leftover feeds which can cause nutrient pollution that is detrimental to fish growth.

The variable labor, which represented payments for hired labor employed in stocking and harvesting activities, also showed a negative parameter estimate. Based on the information gathered, this can be attributed to the practice of using excessive harvesting labor. On the average, stocking activity only required one additional hired labor to perform this operation. The harvesting activity, on the other hand, utilized an average of 10 hired laborers per harvest season. Hence, there is a strong possibility of unrecorded/unreported yield or harvest that may be possibly taken or received by the hired laborers.

All interaction variables turned out to be highly significant indicating that the usage levels of the four inputs were interdependent on each other.

Table 4 also shows the mean of the estimated technical efficiency index for the 23 milkfish cage operators, which was equal to 70.3%. This translates to an average technical inefficiency measure of 29.7%. Both the sigma-squared (σ^2) and gamma (γ) parameters were found significant with the latter being highly significant (1% level) and a value equal to 0.999. This indicates that almost all of the deviations of milkfish production from the frontier function were due to technical inefficiency. This further suggests that the measured inefficiency can be traced to some differences in the cultural practice of the milkfish farmers and not simply attributed to random occurrences.

The analysis of the determinants of technical inefficiency showed that stocking density, feeding rate and farm area were the significant factors that brought about farmer's inefficiency. The operators' education and years of experience in milkfish operation were both found insignificant. This could be explained by the fact that 78% of the respondents either just reached elementary and high school and the average years of experience was only 1.22 years.

The signs of the estimated parameters all conformed to expectation although the values of the coefficients were low. The negative sign of the coefficient of stocking density indicates that an increase in stocking density would decrease inefficiency. Equivalently, this suggests that technical efficiency in milkfish production can be improved by increasing stocking density. In the case of feeding rate, the positive value of the coefficient suggests that inefficiency will increase for every unit increase in feeding rate. This indicates that the milkfish cage operators practiced excessive feed application.

The negative coefficient of farm size indicates that an increase in the number of cages can reduce farmer's inefficiency suggesting the benefits of economies of scale. However, in Taal Lake, farmers are allowed to operate a maximum of five cages with a total area of 500 m^2 (Vista et. al., 2006). These, therefore, imply that only limited efficiency can be exploited through increase in farm size since the average cage holding of the milkfish cage operators was already 330 m^2. Although in practice, cage owners/operators circumvent this law by registering some of their cages under the name of their caretakers. This claim is supported by the reported cage holdings of the 23 milkfish operators which ranged from 1 to 11 cages.

Figure 3 shows the distribution of per farm technical efficiency index of the milkfish cage operators which ranges from 35.3% to 100%. As shown in Figure 3, eleven of the milkfish cage operators (57.7%) have efficiencies higher than the average, five of which have efficiencies ranging from 91%-100%.

Tilapia Cage Operation

Similarly, production function analysis for tilapia operation showed that the translog specification captured the frontier function better than the Cobb-Douglas form by virtue of the significant interaction terms in the model. The results of the frontier production functions specified on a per cage (specified in m^2) and per m^3 units were practically the same with the exception of the significance of the σ^2. Sigma squared turned out insignificant in the per m^3 model but significant on the per cage model, hence, the per cage unit was specified. Likewise, the differences in the estimated technical efficiencies between cages of different depths also turned out to be insignificant and depth of cage was also found an insignificant determinant of technical efficiency.

The results of the translog frontier model for tilapia production is presented in Table 5. The parameter estimates for stocking density, labor and capital were found to be important determinants of output level. The coefficient of stocking density was found to be highly significant and positive with a value of 2.5. This implies that increasing stocking density could further increase output. Given the already high stocking density presently employed by the tilapia cage operators, further increases in stocking density may no longer be advisable. However, since tilapia fingerlings exhibit high mortality rates averaging to about 32% particularly during stocking period, increasing stocking rates is often seen as insurance for any anticipated mortalities during the grow-out process.

The coefficient for labor was found to be statistically significant with a positive coefficient of 8.885. This suggests that increasing labor input particularly on fingerling stocking could similarly improve output. The current use of labor in tilapia culture was very low since the labor use of 1.6 man-days was even allocated to two major activities, namely, stocking and harvesting. Incidentally, fingerling stocking is a relatively laborious and delicate activity. Hence, insufficient labor for this activity could result to poor handling of fingerlings leading to fish stress which is a major cause of mortality.

The coefficient of capital was also found to be highly significant but has a negative sign. This opposite relationship between capital and output is contrary to general expectation. Often, better and more modern infrastructures used in the operation (hence higher depreciation cost) will result to more productivity. The capital variable used in the model was measured in terms of estimated depreciation costs for cage structures, net, raft/boat, storage facilities and equipments. Generally, not all cage operators have storage facilities and equipment, hence, about 70% of these costs was contributed by depreciation of cage structures (70%). Also, since all cages have the same size (100 m^2), the difference in cage value (and consequently, depreciation), can be attributed mainly on the cost of cage construction (material and labor) and age of cages. The unexpected relationship between output and capital in the model can either be explained by the failure of depreciation cost to serve as proxy variable for capital or there is an unusual relationship between capital and output in tilapia culture which warrants further investigation.

As shown also in Table 5, the mean technical efficiency index of the 40 tilapia cage operators is 77.5%, which is relatively higher than that of the milkfish cage operators. Figure 4 shows the distribution of the per-farm technical efficiency index which ranges from 57% to 97.9%. Seventy percent (28) of the 40 tilapia cage operators have efficiencies ranging from 71%-100% with more than half of the operators (52.5%) exhibiting above average efficiency.

With respect to the sources of technical inefficiency among tilapia operators, it is interesting to note that since the model variance (σ^2) was statistically significant while the gamma (γ) parameter was not, it can be concluded that the observed deviations among farmer's yield were mostly due to random errors or statistical noises instead of technical inefficiencies. Apparently, this observation is consistent with the results of the technical inefficiency regression analysis. All the 11 explanatory variables which were assumed to affect inefficiency yielded insignificant coefficients. Furthermore, a comparison of the technical efficiencies of the 26 owner-operators and 14 caretakers showed practically equal averages, 77.5% and 77.6%, respectively (Table 6). All these support the earlier result that yield deviations were simply random and not due to technical inefficiencies.

CONCLUSION AND RECOMMENDATIONS

The results of the study revealed that stocking density and feeding rate are the two most important determinants of technical efficiency for both milkfish and tilapia cage culture operations in Talisay. The combined cost of fingerlings and feeds comprised 90.6% in milkfish production and 94.2% in tilapia production. Parameter estimates for stocking density in the milkfish and tilapia production functions both indicated that their respective outputs can be further improved by increasing the current stocking rates, holding other inputs constant. On the other hand, the coefficients of feeding rate in both functions were found to be negative suggesting the occurrence of overfeeding. Since feeding rate in milkfish operation was about 5 times higher than in tilapia, there are more potential for feed reduction in milkfish operation.

These findings are consistent with the result of the technical inefficiency analysis, specifically for milkfish production.

Based on the result of the cost and return analysis, tilapia cage operation proved to be more profitable than that of milkfish. Net income in the former was found to be two times higher per cage over a relatively shorter culture length. In this regard, the shift to milkfish culture by former tilapia cage operators may not be justified. However, at this point, it would not be prudent to conclude this without a thorough investigation on the issue. Since the milkfish cage operation is still a relatively young industry in Talisay, farmers may still be in the process of learning the technology.

Moreover, some of the respondents claim that the shift of some tilapia cage operators to milkfish production was triggered by the heavy losses incurred by the adoptors of genetically improved farmed tilapia (GIFT) during the late 1990s. Based on the interview, this tilapia strain is susceptible to high mortality during stocking (reaching up to 50%) and even during mature stage (i.e. 3rd month or a month just before harvest). Hence the search for an alternative fish species to grow in Taal Lake lead to a new industry which showed to be promising.

Furthermore, the result of the technical inefficiency analysis for tilapia operation indicated that the deviations from the frontier production were attributable to random errors rather than inefficiency of the operators. In other words, the tilapia cage operators were already efficient in their production process. Occasional low production may be due to environmental conditions beyond the control of the farmers.

Results of the study highlight the environmental aspect of cage culture operation in Taal Lake. Since the trend in aquaculture production had been towards intensive culture system (i.e., high stocking density and high feeding rate), water quality in the lake is being compromised. A key result of the study points to need to reduce feeding rate, especially in the case of milkfish operation. Indirectly, this implies that water quality inside the cage (and eventually the lake ecosystem) can be improved by reducing nutrient overloading through lower feeding rates. While this recommendation will help improve water quality in the lake, it is also cost-saving on the part of the operators.

ACKNOWLEDGMENT

The authors wish to thank WorldFish Center for allowing the use of the data on milkfish and tilapia cage culture operation in Taal Lake, Talisay, Batangas.

REFERENCES

Aigner, D.J., Lovell, C.A.K., and Schmidt, P. (1977), 'Formulation and Estimation of Stochastic Frontier Production Function Models', *Journal of Econometrics*, vol 6, pp. 21-37.

ADB (2005), 'Case Study 6: Tilapia Cage Farming in Lake Taal, Batangas, Philippines', in *An Evaluation of Small-Scale Freshwater Rural Aquaculture Development for Poverty Reduction.*

Battese, G.E. and Coelli, T.J. (1995), 'A Model for Technical Efficiency Effects in Stochastic Frontier Production Function for Panel Data', *Empirical Economics*, vol 20, pp. 325-332.

Bimbao, G.B., Paraguas, F.J., Dey, M.M. and Eknath, A.E. (2000), 'Socioeconomics and production efficiency of tilapia hatchery operations in the Philippines', *Aquaculture Economics and Management*, vol 4 (1&2), pp. 31-46.

Coelli, T.J. (1994) *A Guide to FRONTIER Version 4.1: A Computer Program for Stochastic Frontier Production and Cost Function Estimation*. CEPA Working Paper 96/07. Center for Efficiency and Productivity Analysis, Department of Econometrics, University of New England, Armidale, NSW, 2351, Australia.

Coelli, T.J., Rao, D.S.P. and Battese, G.E. (1998), *An Introduction to Efficiency and Productivity Analysis*. Kluwer Academic Publishers, Boston.

Dey, M.M., Paraguas F.J., Bimbao G.B., and Regaspi, P.B. (2000), 'Technical Efficiency of Tilapia Grow-out Pond Operations in the Philippines', *Aquaculture Economics and Management*, vol 4, pp. 31-47.

Dey, M.M., Paraguas F.J., Srichantuk N., Xinhua Y., Bhatta R. and Dung, L.T.C. (2005), 'Technical Efficiency of Freshwater Pond Polyculture Production in Selected Asian

Countries: Estimation and Implication', *Aquaculture Economics and Management*, vol. 9, pp. 39-63.

Irz, X. and McKenzie, V. (2003) 'Profitability and Technical Efficiency of Aquaculture Systems in Pampanga, Philippines', *Aquaculture Economics and Management*, vol 7 (3&4), pp. 195-211.

Meeusen, W. and van den Broeck, J. (1977), 'Efficiency estimation from Cobb-Douglas production functions with composed errors', *International Economic Review*, vol 18, pp. 435-444.

Panganiban, G.G.F. (2003), Enterprise Study on Tilapia Fishcage Operations in the Taal Lake Areas of Agoncillo and Talisay, Batangas. Unpublished Undergraduate Special Problem. Department of Agribusiness Management, College of Economics and Management, University of the Philippines Los Baños, College, Laguna.

Sharma, K.R. and Leung, P.S. (2000a), 'Technical Efficiency of Carp Pond Culture in South Asia: An Application of a Stochastic Meta-production Frontier Model', *Aquaculture Economics and Management*, vol 4 (3/4), pp. 169-189.

Sharma, K.R. and Leung, P.S. (2000b), 'Technical Efficiency of Carp Production in India. A Stochastic Frontier Production Function Analysis', *Aquaculture Research*, vol 31, pp. 937-948.

Tan, R.L., Higuchi, T. and Honma, T. (1992), 'Econometric Approach to Inefficiency Estimation and Regulatory Policy Formulation for Freshwater Resource Utilization: The Case of Cage Culture of Tilapia in Sampaloc Lake, Philippines' (in Japanese), *Journal of Fisheries Economy*, vol. 37, pp. 21-46.

Tan, R.L. (1992), 'Bioeconomic Approach to Investment and Regulatory Policy Formulation for Freshwater Resource Utilization: The Case of Cage Culture of Tilapia in Sampaloc Lake, Philippines', Ph.D. Dissertation, Institute of Agriculture and Forestry, University of Tsukuba.

Tan, R.L., Higuchi, T. and Honma, T. (1992), 'Econometric Approach to Inefficiency Estimation and Regulatory Policy Formulation for Freshwater Resource Utilization: The Case of Cage Culture of Tilapia in Sampaloc Lake, Philippines', *Journal of Fisheries Economy*, vol. 37, no.21, pp. 1-26.

Tan, R.L., Baskiñas, L.T.P. and Garcia, P.G. (1994), 'Socio-economic Profiling and Analysis of Fishcage Culture and Capture Fisheries in Taal Lake', report submitted to the Philippine Council for Aquatic and Marine Research and Development (PCAMRD), DOST.

Vista, A., Norris, P., Lupi, F. and Bernsten, R. (2006), 'Nutrient Loading and Efficiency of Tilapia Cage Culture in Taal Lake, Philippines', *The Philippines Agricultural Scientist*, vol. 89, no. 1, pp. 48-57.

Table 1. General profile of milkfish and tilapia cage operators.

Characteristics	Milkfish Cage Operators	Tilapia Cage Operators	
A. No. of Respondents	23 (100%)	40 (100%)	
B. Tenure Status			
Owner-Operator	23 (100%)	26 (65%)	
Caretaker			14 (35%)
C. Age (Average)	32	47	34
D. Sex			
Male	23	23	14
Female		3	
E. Household Size (Average)	3	4	4
F. Marital Status			
Married	15 (65%)	16 (62%)	10 (71%)
Single	8 (35%)	7 (27%)	4 (29%)
Widowed		3 (11%)	
G. Educational Background			
Elementary	4 (17%)	7 (27%)	2 (14%)
High School	14 (61%)	12 (46%)	9 (64%)
College	5 (22%)	7 (27%)	3 (21%)
H. Average Years of Experience in Cage Operation			
Tilapia	-		
Milkfish	1.22	5.7	2.5
		-	-

Table 2. Production practices of milkfish and tilapia cage operators in Talisay, Taal Lake.

Characteristics	Milkfish Cage Operators (n = 23)	Tilapia Cage Operators (n = 40)
A. Cage Structures		
Average cage size (m^2)	100 (0)	100 (0)
Average farm size (m^2)	330 (263)	577 (712)
Average cage depth (m)	7.46 (0.5)	7.0 (1.35)
B. Stocking		
Average stocking per cage (fingerlings)	8,252 (2,702)	37,750 (11,872)
Manner of stocking		
Direct	23 (100%)	20 (50%)
Indirect		20 (50%)
C. Feeding		
Average amount of feeds applied per cage per culture cycle (kgs)	7,554.3 (2,614.4)	1,473.7 (1472.4)
Average culture/feeding period (months)	5.83 (0.76)	5.1 (0.73)
Manner of application		
Broadcast	23 (100%)	39 (98%)
Hung in nets		1 (1%)
Frequency of feed application per day		
2 times		6 (15%)
3 times	21 (91%)	33 (83%)
4 times (and up)	2 (9%)	1 (2%)
D. Harvesting		
Average production per cage per culture cycle (tons)	2.68 (1.22)	1.42 (0.57)

Note: Values in parentheses without percentages are standard deviations of the values.

Table 3 . Comparative cost and return (Php) of milkfish and tilapia cage operation in Talisay, Taal Lake.

	Milkfish	%	Tilapia	%
Gross Return	184,920		73,840	
Costs				
Fingerlings	26,159	15.3	17,869	39.6
Feeds	128,503	75.3	24,640	54.6
Labor	6,011	3.5	310	0.7
Depreciation	5,895	3.5	1147	2.5
Others	4,023	2.4	1,131	2.5
Sub-Total	170,591	100	45097	100
Net Income per Cage	14,329		28,743	
Cage Size (m^2)	100		100	
Net Income per m^2	143.29		287.43	
Culture Cycle (months)	5.8		5.1	

Notes: 1) Values are averages of milkfish and tilapia cage operations
2) Discrepancies in percentage figures are due to rounding.

Table 4. Maximum-likelihood estimates of the stochastic translog frontier production function and technical inefficiency model for milkfish cage operation in Talisay, Taal Lake.

Variables	Parameters	MLE Estimates	Standard Error	t-ratio
Stochastic frontier				
Constant	β_0	-7.823**	0.975	-8.020
Ln X_1 (stocking density)	β_1	101.358**	0.847	119.691
Ln X_2 (feeding rate)	β_2	-166.192**	0.847	-196.171
Ln X_3 (labor)	β_3	-2.920**	0.845	-3.454
Ln X_4 (capital)	β_4	70.635**	0.847	83.416
Ln X_5 ($LnX_1 \times Ln X_2$)	β_5	30.133**	0.725	41.561
Ln X_6 ($LnX_1 \times LnX_3$)	β_6	-59.072**	0.725	-81.451
Ln X_7 ($LnX_2 \times LnX_3$)	β_7	98.667**	0.727	135.739
Ln X_8 ($LnX_1 \times LnX_4$)	β_8	-71.996**	0.728	-98.852
Ln X_9 ($LnX_3 \times LnX_4$)	β_9	-36.672**	0.725	-50.585
Ln X_{10} ($LnX_2 \times LnX_4$)	β_{10}	38.009**	0.725	52.392
Technical Inefficiency Model				
Constant	δ_0	3.443*	1.163	2.959
Z_1 (culture period)	δ_1	0.046	0.117	0.390
Z_2 (operators' age)	δ_2	0.019	0.015	1.327
Z_3 (operators' education)	δ_3	-0.194	0.091	-2.134
Z_4 (years in aqua-business)	δ_4	-0.031	0.058	-0.538
Z_5 (depth of cage)	δ_5	-0.242	0.128	-1.882
Z_6 (household size)	δ_6	0.040	0.086	0.463
Z_7 (farm area)	δ_7	-0.001*	0.0006	-2.315
Z_8 (stocking density)	δ_8	-0.0001*	0.00006	-2.229
Z_9 (feeding rate)	δ_9	0.0001*	0.00005	2.661
Z_{10} (hired labor)	δ_{10}	0.000008	0.00002	0.353
Z_{11} (capital)	δ_{11}	-0.0001	0.00007	-1.609
Variance Parameters				
Sigma-squared	σ^2	0.033	0.018	1.807
Gamma	γ	0.999**	0.064	15.528
Log-likelihood value		13.661		
Mean technical efficiency index		70.3%		

**significant at $\alpha = 0.01$; * significant at $\alpha = 0.05$

Table 5. Maximum-likelihood estimates of the stochastic translog frontier production function and technical inefficiency model for tilapia cage operation in Talisay, Taal Lake.

Variables	Parameters	MLE Estimates	Standard Error	t-ratio
Stochastic frontier				
Constant	β_0	-20.450**	0.992	-20.624
Ln X_1 (stocking density)	β_1	2.499**	0.569	4.394
Ln X_2 (feeding rate)	β_2	-0.387	0.926	-0.418
Ln X_3 (labor)	β_3	8.885**	0.942	9.396
Ln X_4 (capital)	β_4	-4.764**	0.917	-5.193
Ln X_5 ($LnX_1 \times Ln X_2$)	β_5	-0.017	0.157	-0.110
Ln X_6 ($LnX_1 \times LnX_3$)	β_6	-0.919**	0.196	-4.700
Ln X_7 ($LnX_2 \times LnX_3$)	β_7	0.104	0.258	0.404
Ln X_8 ($LnX_1 \times LnX_4$)	β_8	0.413**	0.132	3.135
Ln X_9 ($LnX_3 \times LnX_4$)	β_9	0.078	0.211	0.369
Ln X_{10} ($LnX_2 \times LnX_4$)	β_{10}	-0.022	0.269	-0.082
Technical Inefficiency Model				
Constant	δ_0	0.689	0.959	0.718
Z_1 (culture period)	δ_1	-0.060	0.110	-0.541
Z_2 (operators' age)	δ_2	-0.002	0.007	-0.301
Z_3 (operators' education)	δ_3	0.014	0.035	0.390
Z_4 (years in aqua-business)	δ_4	0.018	0.020	0.884
Z_5 (depth of cage)	δ_5	-0.032	0.046	-0.704
Z_6 (household size)	δ_6	-0.033	0.043	-0.769
Z_7 (farm area)	δ_7	-0.0002	0.0003	-0.536
Z_8 (stocking density)	δ_8	0.000007	0.00001	0.746
Z_9 (feeding rate)	δ_9	-0.0002	0.0003	-0.691
Z_{10} (hired labor)	δ_{10}	0.0008	0.002	0.512
Z_{11} (capital)	δ_{11}	-0.00007	0.0003	-0.242
Variance Parameters				
Sigma-squared	σ^2	0.088**	0.021	4.108
Gamma	γ	0.331	0.299	1.106
Log-likelihood value		-6.474		
Mean technical efficiency index		77.5%		

** significant at $\alpha = 0.01$

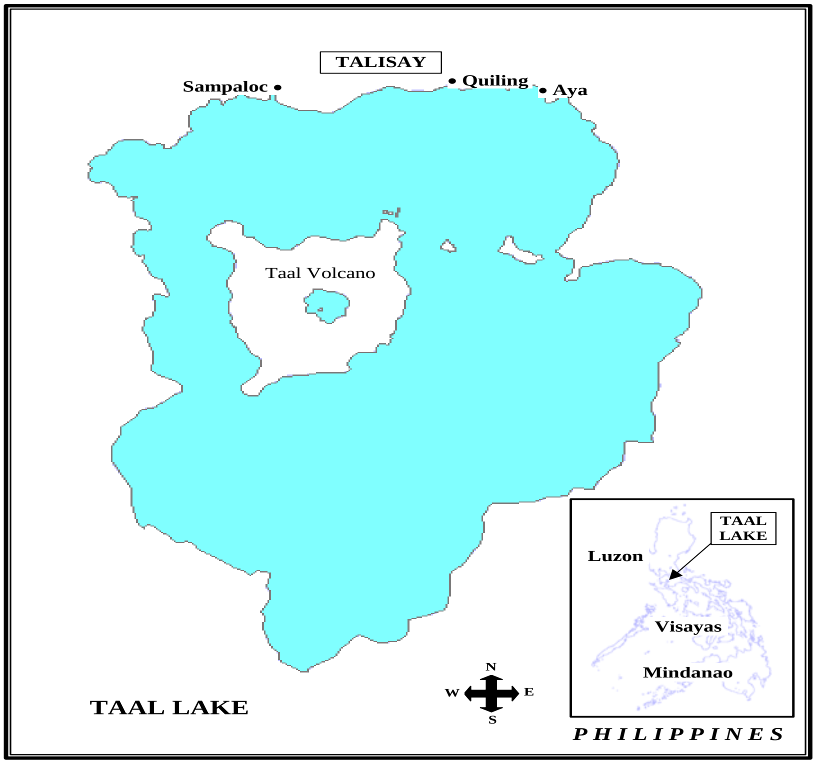

Figure 1. Map of Taal Lake showing the study sites.

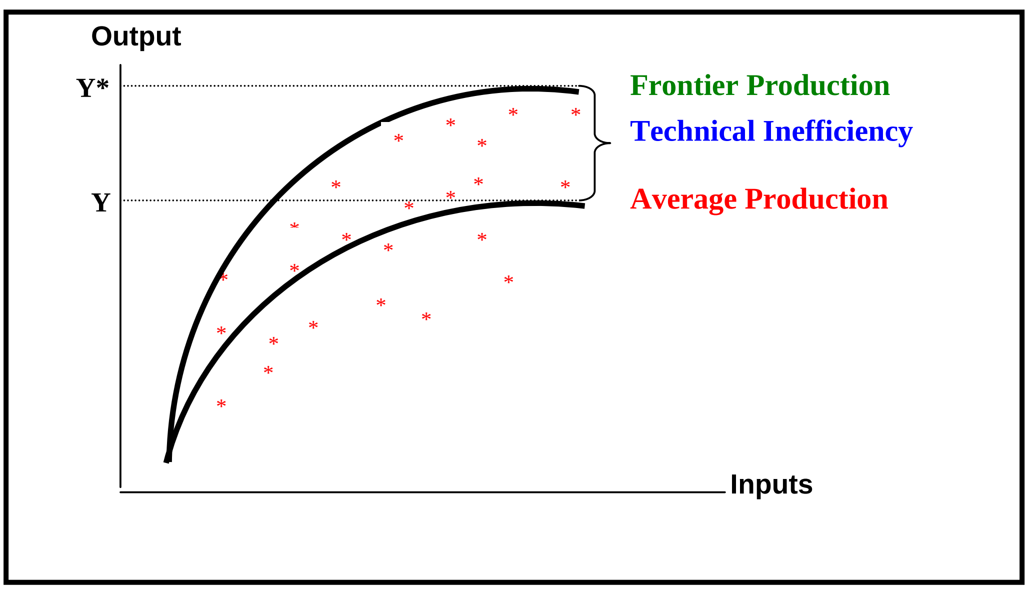

Figure 2. Measure of technical inefficiency based on frontier vs. average production functions.

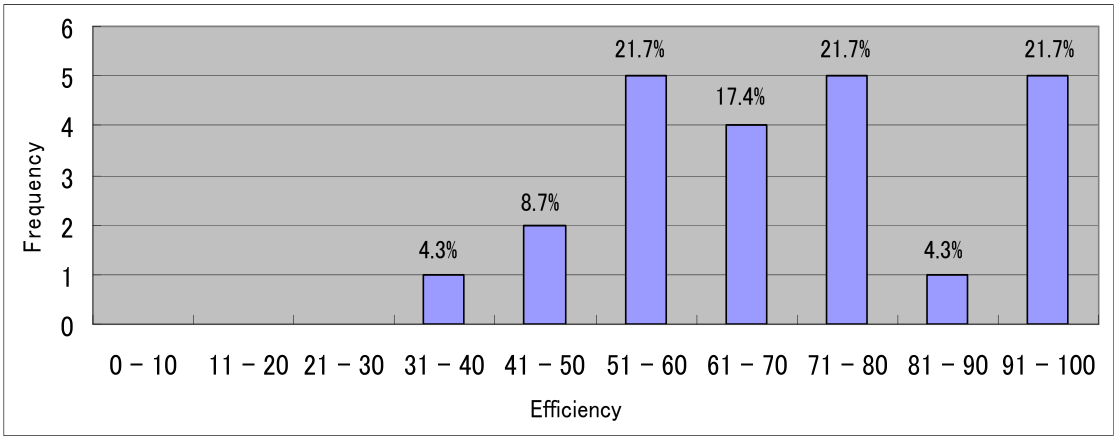

Figure 3. Frequency distribution of technical efficiency of milkfish cage operators in Talisay.

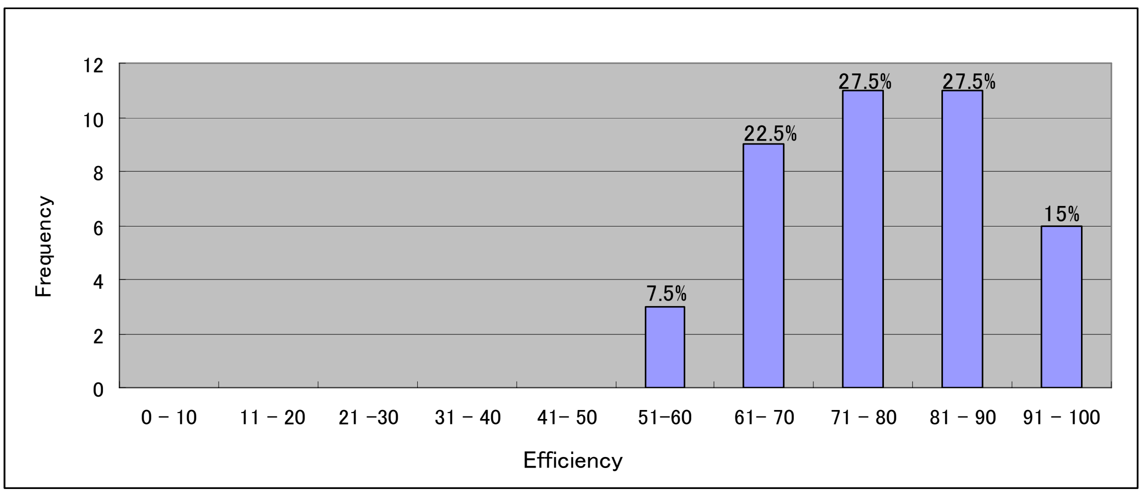

Figure 4. Frequency distribution of technical efficiency of tilapia cage operators in Talisay.