TECHNICAL EFFICIENCY OF GENETICALLY IMPROVED FARMED TILAPIA (GIFT) CAGE CULTURE OPERATIONS IN THE LAKES OF LAGUNA AND BATANGAS, PHILIPPINES

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ABSTRACT

In an earlier paper, a descriptive *ex post* study to assess the adoption and farm-level impacts of Genetically Improved Farmed Tilapia (GIFT) in the Philippines was conducted covering the top three producing provinces: Region II (Isabela, Nueva Viscaya and Quirino); Region III (Nueva Ecija and Pampanga); and Region IV (Laguna and Batangas). This paper focuses on Region IV and takes a closer look and more in depth analysis of the tilapia cage culture operations in Lakes Sampaloc and Palakpakin in Laguna, and Laurel and Agoncillo in Taal Lake, Batangas. The technical efficiencies of the culture operations were estimated using translog stochastic frontier production function and the statistically significant factors affecting technical inefficiency were determined. Comparisons were made according to the four strain groups identified in the previous study: GIFT, GIFT-derived, non-GIFT and unspecified tilapia strains. In all four study areas, deviations from the frontier production functions were practically due to technical inefficiency. Thus, the strategy to improve their productivity is to address the factors that have been identified in their respective technical inefficiency functions.

Key words: Translog stochastic frontier function, Taal Lake, Sampaloc Lake, productivity, inefficiency

INTRODUCTION

Recognizing the need for a comprehensive *ex post* study to assess the adoption and farm-level impacts of Genetically Improved Farmed Tilapia (GIFT), the WorldFish Center initiated the project entitled "Assessing the farm-level impact of Genetically Improved Farmed Tilapia (GIFT) in China and Philippines". For the Philippine component, tilapia producers were interviewed from the top three producing provinces: Region II (Isabela, Nueva Viscaya and Quirino); Region III (Nueva Ecija and Pampanga); and Region IV (Laguna and Batangas). Regions II and III are basically pond-based while Region IV is lake-based (cage culture). Based on information provided by fish-farmer respondents which were counterchecked (in cases possible) with the identified hatcheries where the fingerlings were sourced, the fingerlings stocked were grouped into four: 1) GIFT (includes strains of GIFT, Genomar Supreme Tilapia and GIFT Bilugan); 2) GIFT-derived (includes Genetically

Enhanced Tilapia-Excellent or GET-EXCEL strain and any crossbreeds of GIFT or GIFT-derived with other strains); 3) non-GIFT (includes Freshwater Aquaculture Center Selected Tilapia or FaST, Israel, Mosambique, Singapore, Egyptian, Thailand, Taiwan and crossbreeds among non-GIFT); and 4) unspecified (includes Nilotica, Tagalog, Danao, Sex reversed, GMT/YY-male, Regular, Pla-pla, Ordinary, and any crossbreeds of unspecified strains. The results of adoption analysis in the three regions revealed that only 6.4% of the respondents for the three regions adopted the GIFT strain and 48.3% cultured GIFT-derived strains (GET-EXCEL, any crossbreeds of GIFT or GIFT-derived with other strains). The remaining respondents reported using non-GIFT (17.4%) and unspecified strains (27.9%). Based on the farmers' ratings and the preliminary analysis of the reported production information, the GIFT and GIFT-derived strains generally did not perform any better compared to the other strains (Pemsl et al, 2008).

This paper focuses on Region IV and takes a closer look and more in depth analysis of the tilapia cage culture operations in the lakes of San Pablo City in Laguna and Taal Lake in Batangas. The technical efficiency of the culture operations of the four groups of tilapia strains are assessed to substantiate and/or refute the results of preliminary analysis that the GIFT and GIFT-derived strains generally did not perform any better compared to the other strains on a per specific location basis.

The paper is divided into three major sections. Section 2 discusses the analytical models used in the study namely: a) stochastic frontier production function; c) technical efficiency estimation and c) multivariate analysis of the determinants of technical inefficiency. Section 3 focuses on the results of the study and the final section presents the conclusion and recommendation.

The general objective of the study is to assess the technical efficiency of GIFT/GIFT-derived versus the other tilapia strains in San Pablo lakes in Laguna and Taal Lake in Batangas. Specifically, this paper aims to: (1) compare the input-output relationships of these tilapia cultures; (2) measure the technical efficiencies of these tilapia cultures and to identify the factors that affect these; and (3) formulate recommendations towards improving efficiency and profitability of the respective culture systems.

METHODOLOGY

Data source

This study made use of data on tilapia cage culture operations in the lakes of Laguna and Batangas which were collected in 2006/2007 for the Philippine component of the WorldFish Center project entitled "Assessing the farm-level impact of Genetically Improved Farmed Tilapia (GIFT) in China and Philippines" using stratified sampling with proportional allocation. Lakes Sampaloc and Palakpakin in Laguna and two coastal barangays in Taal Lake, Laurel and Agoncillo, were used for this technical efficiency analyses. These made use of 55 samples in Sampaloc Lake, 44 in Palakpakin, 58 in Laurel and 67 in Agoncillo. The production data provided by tilapia cage operators were averages of inputs and outputs in their multiple cage operation.

The survey sites are shown in Figures 1 and 2.

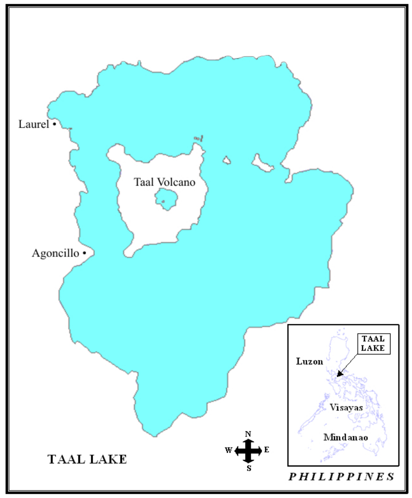

Fig. 1. Map of Taal Lake showing the study sites.

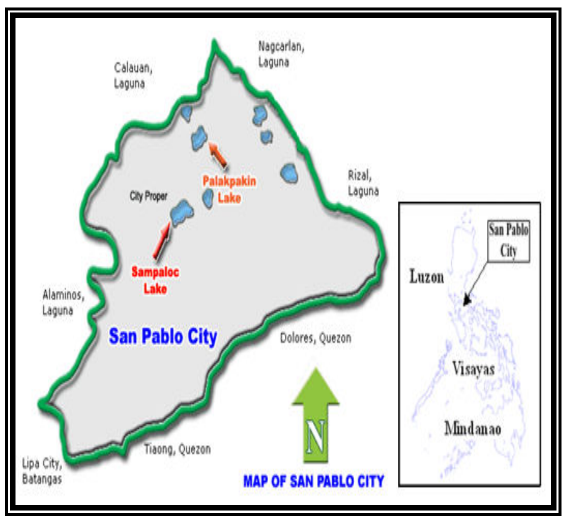

Figure 2. Map of San Pablo City showing the study sites.

Analytical method

The technical efficiency model used in this study is based on the works of Aigner *et al.*, (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;
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.
U_i is a non-negative random error term associated with technical inefficiency in production;

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.*, $U_i \sim |N(\mu_i, \sigma_u^2)|$. 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].

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. Specifically, technical efficiency (TE_i) of the i^{th} farm is derived as follows:

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

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 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 entirely due to technical inefficiency (Coelli *et al.,* 1998).

To determine the factors that explain farmer's efficiency, either the TE or TI (Technical Inefficiency = 100% - TE) 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 or TI = f (farm-specific factors like water quality, depth *etc.*; and farmer-specific factors, like age, education, and training, *etc.*)

This study obtained the maximum-likelihood estimates (MLEs) of the stochastic frontier production function and the parameters of the technical inefficiency regression simultaneously using the FRONTIER Version 4.1 software (Coelli, 1994).

Empirical model

Results of several regression runs indicated that the stochastic translog production frontier function fits well and adequately captured the production behavior of the tilapia cage culture operations in the four study areas. The final model used for Lakes Sampaloc and Palakpakin was specified as:

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

where: Ln Y - observed farm yield (kg m^{-2})

$Ln\ X_1$ - stocking density (no. of fingerlings m^{-2})
$Ln\ X_2$ - feeding rate (feeds applied in kg/fish m^{-2}/culture length^{-1})
$Ln\ X_3$ - labor (family and hired man-days m^{-2})
$Ln\ X_4$ - capital (depreciation value of fixed assets over culture length)
$Ln\ X_5$ - $LnX_1 \times LnX_2$
$Ln\ X_6$ - $LnX_1 \times LnX_3$
$Ln\ X_7$ - $LnX_1 \times LnX_4$
$Ln\ X_8$ - $LnX_2 \times LnX_3$
$Ln\ X_9$ - $LnX_2 \times LnX_4$
$Ln\ X_{10}$ - $LnX_3 \times LnX_4$
subscript i refers to ith observation in the sample
Ln represents natural logarithm

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

$$TI_i = \delta_o + \sum_{j=1}^{11} \delta_j Z_{ij}$$

where: Z_1 - farm area (m^2)
Z_2 - cage area (m^2)
Z_3 - operators' age (years)
Z_4 - education level (years)
Z_5 - depth of cage (m)
Z_6 - price of fingerlings (pesos)
Z_7 - mortality (fish m^{-2})
Z_8 - operational experience (years)
Z_9 - culture period
Z_{10} - dummy for GIFT strain
Z_{11} - dummy for GIFT-derived strain
Z_{12} - dummy for non-GIFT m^2) strain

These models were also specified for the Laurel and Agoncillo data with two differences in the farm-specific TI model. Cage size was omitted since all cages are of size 100 m^2 in these study areas (as per Municipal Ordinance 01-96). In addition, dummy for type of operation (owner-operated versus caretaker-operated) was included since about half of the farms represented by the respondents in both study areas were caretaker-operated.

RESULTS AND DISCUSSION

With the main objective of assessing the technical efficiencies of the GIFT and GIFT-derived strains versus the other tilapia strains cultured in the four study areas, comparative analyses of these tilapia strains were done. The four strain groupings identified by Tongruksawattana (2007) were used: 1) GIFT 2) GIFT-derived 3) non-GIFT; and 4) unspecified. The unspecified group was used as the based dummy in the technical inefficiency function. The results of the regression analyses of the four study areas are individually presented beginning with Sampaloc Lake and comparisons with the succeeding results are done progressively.

Sampaloc Lake

In the frontier production function (Table 1), stocking density and capital turned out to be statistically significant determinants of yield**.** On the one hand, a 10% increase in stocking density will bring about a 15% increase in yield. Of the 55 respondents, nine used GIFT-derived strains, 12 used non-GIFT, 34 used the unspecified strains and none for GIFT. On the other hand, a 10% increase in capital expenditure would increase yield by 17%. Capital expenditure represented by depreciation costs of cage, equipments *etc.* per culture period is expected to have a positive contribution on yield as these promote better growing environment and operation. The variance parameters σ^2 and γ are found highly significant. In particular, the value of γ is 0.998 which implies that the production deviations from the frontier functions are practically due to technical inefficiency. The mean technical efficiency index in Sampaloc Lake is relatively low, 18.3% giving a relatively high technical inefficiency of 81.7% (= 100% – 18.3%).

Table 1. Maximum-likelihood estimates of the stochastic frontier production and technical inefficiency model for tilapia cage operation in Lakes Sampaloc and Palakpakin, Laguna.

Variables	Parameters	Sampaloc Lake (n=55)			Palakpakin Lake (n=44)		
		MLE Estimates	Standard Error	t-ratio	MLE Estimates	Standard Error	t-ratio
Stochastic Frontier							
Constant	β_0	-4.135	2.451	-1.688	-4.288	3.352	-1.279
Ln X_1 (stocking density)	β_1	1.575	0.628	2.510*	1.733	0.883	1.963*
Ln X_2 (feeding rate)	β_2	0.634	0.793	0.800	-0.896	0.611	-1.467
Ln X_3 (labor)	β_3	-0.484	0.801	-0.604	-1.010	0.797	-1.267
Ln X_4 (capital)	β_4	1.701	0.735	2.315*	0.335	1.298	0.258
Ln X_5 (Ln X_1 x Ln X_2)	β_5	-0.219	0.192	-1.141	0.183	0.183	1.005
Ln X_6 (Ln X_1 x Ln X_3)	β_6	-0.046	0.202	-0.229	0.222	0.202	1.099
Ln X_7 (Ln X_1 x Ln X_4)	β_7	-0.339	0.208	-1.638	-0.015	0.300	-0.050
Ln X_8 (Ln X_2 x Ln X_3)	β_8	-0.221	0.093	-2.377**	-0.068	0.135	-0.501
Ln X_9 (Ln X_2 x Ln X_4)	β_9	0.021	0.197	0.105	0.121	0.223	0.545
Ln X_{10} (Ln X_3 x Ln X_4)	β_{10}	0.071	0.163	0.434	0.194	0.198	0.983
Technical Inefficiency Model							
Constant	δ_0	-0.383	1.546	-0.248	1.339	0.740	1.808
Z_1 (farm area)	δ_1	0.000	0.000	-0.074	0.000	0.000	0.950
Z_2 (cage area)	δ_2	0.000	0.002	0.196	0.002	0.001	1.779
Z_3 (age)	δ_3	0.004	0.008	0.515	-0.010	0.009	-1.033
Z_4 (years in school)	δ_4	0.103	0.022	4.672**	-0.045	0.032	-1.431
Z_5 (depth of cage)	δ_5	-0.040	0.057	-0.700	0.042	0.088	0.480
Z_6 (price of fingerling)	δ_6	-0.290	0.126	-2.294*	-1.376	0.526	-2.617*
Z_7 (mortality)	δ_7	0.032	0.006	4.948**	0.006	0.002	2.295*
Z_8 (years of experience)	δ_8	0.010	0.011	0.891	-0.006	0.012	-0.491
Z_9 (culture period)	δ_9	0.110	0.050	2.193*	0.122	0.058	2.113*
Z_{10} (dummy for GIFT)	δ_{10}	0.000	1.000	0.000	0.884	0.466	1.897
Z_{11} (dummy for GIFT-derived)	δ_{11}	0.303	0.156	1.941	0.466	0.145	3.207**
Z_1 (dummy for non-GIFT)	δ_{12}	-0.316	0.211	-1.493	0.074	0.332	0.221
Variance Parameters							
Sigma-squared	σ^2	0.212	0.015	14.435**	0.096	0.028	3.392**
Gamma	γ	0.998	0.465	2.146*	1.000	0.000	23112.497**
Log-likelihood value				-34.204			-10.102
Mean Technical Efficiency index				0.1828			0.2802

*significant at α=5%
**significant at α=1%

In the technical inefficiency function, contrary to expectation, the technical inefficiencies of the three strain groupings were not significantly different as indicated by the t-values of the dummy variables and the test of means of technical efficiencies among these strain groups. The highly significant determinants of inefficiency were educational level or years of schooling, price of fingerlings, mortality, and culture period. Mortality and culture period have the expected positive signs, which mean that the higher the mortality and the longer the culture period, the higher the inefficiency. The average percent mortalities for all strains were relatively high, 61.7%, 76.5% and 65.16% for GIFT-derived, non-GIFT and unspecified, respectively (Table 2).

Table 2. Averages of tilapia production function and efficiency factors in Lakes Sampaloc and Palakpakin, Laguna..

				Sampaloc Lake					
Strain Classification	**N**	**Qty**	**SD**	**Feeds**	**Labor**	**Capital**	**Farm Area**	**Cage Area**	**AGE**
GIFT	0	-	-	-	-	-	-	-	-
GIFT-derived	9	1.48	31.08	0.14	0.39	6.27	527.78	163.89	48.89
Non-GIFT	12	2.14	55.27	0.06	0.27	11.24	650.00	131.32	47.50
Unspecified	34	2.16	44.14	0.09	0.46	5.12	507.35	120.97	47.56
All	55	2.05	44.43	0.09	0.41	6.65	541.82	130.25	47.76
Strain Classification	YRSCHOOL	Depth	Fing. Price	Culture Period	Yrs of exp	MR (pcs m^{-2})	%MR (pcs/SD)	TE Estimates	Fingerling Size
GIFT	-	-	-	-	-	-	-	-	-
GIFT-derived	9.56	6.00	0.79	5.06	15.11	21.07	61.69	0.17	13.33
Non-GIFT	10.42	6.81	0.62	5.17	19.50	43.61	76.52	0.13	14.67
Unspecified	9.50	6.04	0.72	4.53	15.68	31.52	65.16	0.20	13.56
All	9.71	6.20	0.71	4.75	16.42	32.45	67.07	0.18	13.76
				Palakpakin Lake					
Strain Classification	**N**	**Qty**	**SD**	**Feeds**	**Labor**	**Capital**	**Farm Area**	**Cage Area**	**AGE**
GIFT	1	2	60.00	0.18	0.16	5.38	400.00	100.00	47.00
GIFT-derived	13	2.29	42.76	0.08	0.56	6.54	481.25	126.04	41.25
Non-GIFT	3	2.46	26.50	0.10	0.29	4.38	433.33	166.67	48.00
Unspecified	24	2.41	62.78	0.09	0.26	7.00	500.00	151.46	44.17
All	44	2.36	52.96	0.09	0.37	6.62	486.36	142.08	43.43
Strain Classification	YRSCHOOL	Depth	Fing. Price	Culture Period	Yrs of exp	MR (pcs m^{-2})	%MR (pcs/SD)	TE Estimates	Fingerling Size
GIFT	7.00	7.00	0.65	4.00	11.00	51.00	85.00	0.16	14.00
GIFT-derived	8.63	5.00	0.55	5.88	11.63	27.15	62.61	0.21	14.00
Non-GIFT	7.33	4.33	0.67	6.00	19.67	16.75	62.73	0.38	13.33
Unspecified	8.54	5.02	0.59	6.50	11.88	46.60	51.27	0.32	13.63
All	8.45	5.01	0.58	6.18	12.30	37.59	56.94	0.28	13.75

Note: SD - stocking density
MR – mortality rate

The price of fingerlings has a negative sign, which means, the higher the price, the lower the inefficiency. The average price of GIFT-derived (Php 0.79 $fingerling^{-1}$) which was perceived to be of better quality was higher compared to non-GIFT (Php 0.62 $fingerling^{-1}$) and unspecified (Php 0.72 $fingerling^{-1}$) but are not significantly different in the test of means. However, the yield obtained from GIFT-derived (1.48 kg m^{-2}) was even lower than non-GIFT (2.14 kg m^{-2}) and unspecified (2.16 kg m^{-2}). The positive coefficient of years of schooling indicated that the higher the educational level, the higher the inefficiency which was also contrary to expectation. The respondents who reached elementary education had the highest mean efficiency compared to those who reached high school and college education for GIFT-derived, non-GIFT and unspecified strain, average of 27%. In addition, age and years of experience turned out insignificant and need further investigation.

Palakpakin Lake

As shown also in Table 1, in the frontier production function, stocking density turned out as the sole significant determinant of yield. A 10% increase in the stocking density will increase yield by 17.3%. Of the 44 respondents, 16 used GIFT-derived strains, 24 used the unspecified strains, only one used GIFT and three for non-GIFT. The highly significant γ with a value of 1.0 indicates that all of the production deviations from the frontier functions are entirely due to technical inefficiency. Although the mean technical efficiency index of Palakpakin Lake (28%) is higher than Sampaloc Lake, it is still relatively low giving a technical inefficiency of 71.9%. In the technical inefficiency model, mortality, culture period and price of fingerlings also turned out to be significant determinants of technical inefficiency having the same signs as in Sampaloc Lake. However, years of schooling was not significant and contrary to expectation, the dummy for GIFT-derived turned out highly significant with a positive coefficient, indicating that GIFT-derived is less efficient than the other strain groups. The average technical efficiency of the 16 operators who used GIFT-derived strains is 21%, compared to 32% average technical efficiency of 24 operators who used unspecified strains, 38% for the three cases for non-GIFT and 16% for the one case of GIFT (Table 3).

Table 3. Data averages of tilapia production function and efficiency factors in Laurel and Agoncillo, Taal Lake, Batangas.

Laurel									
Strain Classification	**N**	**Qty**	**SD**	**Feeds**	**Labor**	**Capital**	**Farm Area**	**Cage Area**	**AGE**
GIFT	1	40.00	1300.00	0.08	1.27	38.00	100.00	100	28.00
GIFT-derived	5	32.53	1000.00	0.11	0.35	59.99	440.00	100	35.20
Non-GIFT	3	31.56	2100.00	0.01	0.08	19.37	1566.67	100	49.67
Unspecified	49	43.72	1136.94	0.08	0.81	35.39	414.29	100	40.20
All	58	42.07	1177.76	0.08	0.74	36.73	470.69	100	40.05
Strain Classification	**YRSCHOOL**	**Depth**	**Fing. Price**	**Culture Period**	**Yrs of exp**	**MR (pcs m^{-2})**	**%MR (pcs/SD)**	**TE Estimates**	**Fingerling Size**
GIFT	10.00	10.00	0.30	7.00	3.00	960.00	73.85	0.17	22.00
GIFT-derived	9.40	10.60	0.37	4.70	11.20	865.62	82.76	0.28	16.40
Non-GIFT	11.33	9.33	0.35	6.00	20.33	1993.76	93.77	0.59	20.67
Unspecified	9.27	9.49	0.31	5.60	11.55	972.27	81.16	0.39	17.53
All	9.40	9.59	0.32	5.57	11.83	1015.70	81.83	0.39	17.67
Agoncillo									
Strain Classification	**N**	**Qty**	**SD**	**Feeds**	**Labor**	**Capital**	**Farm Area**	**Cage Area**	**AGE**
GIFT	1	20.00	1000.00	0.04	0.42	5.13	200.00	100	23.00
GIFT-derived	12	45.62	758.33	0.09	0.55	23.39	266.67	100	37.58
Non-GIFT	3	51.87	1333.33	0.11	0.99	32.91	233.33	100	32.33
Unspecified	50	39.39	907.40	0.14	0.72	34.60	204.00	100	37.92
All	66	40.80	901.06	0.13	0.70	32.04	216.67	100	37.38
Strain Classification	**YRSCHOOL**	**Depth**	**Fing. Price**	**Culture Period**	**Yrs of exp**	**MR (pcs m^{-2})**	**% MR (pcs/SD)**	**TE Estimates**	**Fingerling Size**
GIFT	10.00	7.00	0.35	6.00	9.00	920.00	92.00	0.15	17.00
GIFT-derived	8.33	7.17	0.38	6.25	8.88	638.44	80.94	0.58	17.08
Non-GIFT	10.00	7.00	0.33	6.33	6.33	1222.07	92.55	0.48	20.33
Unspecified	8.66	7.58	0.88	5.72	9.34	769.54	82.43	0.44	16.94
All	8.68	7.47	0.76	5.85	9.11	768.56	82.76	0.46	17.12

The average mortality rates for GIFT-derived was 62.6%, and 51.3% for unspecified, 62.7% for non-GIFT and 85% for GIFT were not significantly different in the test of means. The average culture periods of the fours strains were GIFT (4 months), GIFT-derived (5.88 months), non-GIFT (6 months) and unspecified (6.5 months). Comparing average fish sizes at harvest (GIFT: 4.5 pcs/kg; GIFT-derived: 7.1 pcs kg^{-1}; non-GIFT: 3.96 pcs kg^{-1}; and unspecified: 6.71 pcs kg^{-1}) and deriving growth rate by dividing these by average culture periods (1.12 kg mo^{-1}; 1.21 kg mo^{-1}; 0.66 kg mo^{-1} and 1.03 kg mo^{-1}, respectively), the GIFT and GIFT-derived strains have relatively better growth. Taking the fingerling size and price into consideration, Non-GIFT strain turns out to be the most expensive with an average of Php0.67 pesos/fingerling compared to GIFT (Php 0.65 $fingerling^{-1}$), GIFT-derived (Php 0.55 $fingerling^{-1}$), and unspecified strains (Php 0.59 $fingerling^{-1}$) of fingerling sizes of 13-14. This explains the negative sign of fingerling price size which indicated that lower inefficiency for higher price fingerlings.

Laurel

At the outset, it is important to note the mark differences in the operation and performance of Lakes Sampaloc and Palakpakin in Laguna with Laurel and Agoncillo in Taal Lake, Batangas. The average stocking densities in Laurel and Agoncillo were 1,178 fingerlings m^{-2} and 901 fingerlings m^{-2}, respectively compared toonly 44 fingerlings m^{-2} in Sampaloc Lake and 53 fingerlings m^{-2} in Palakpakin Lake (Tables 3 and 4). In turn, the average yield in Laurel is 42.07 kg m^{-2} and 40.8 kg m^{-2} in Agoncillo, which were about 20 times higher than those in Sampaloc Lake (2.05 kg m^{-2}) and Palakpakin Lake (2.36 kg m^{-2}). Thus, despite the higher average mortality rates in Laurel (81.8%) and Agoncillo (82.8%) compared to Sampaloc Lake (67.1%) and Palakpakin Lake (56.9%), the average effective stocking densities (stocking density less mortality per m^2) of Laurel and Agoncillo were still about 10 times higher than those in Sampaloc Lake and Palakpalakin.

In the frontier production function (Table 2), only capital turned out to be the significant determinant of yield. On the contrary, the sign was negative. A 10% increase in capital will reduce yield by 31%. Since capital was represented by depreciation costs for cage and equipments used in the operation, it is difficult to draw a logical explanation from the data as to why the opposite effect came about even if the average capital expenditure in Laurel (Php 36.73 m^{-2})) was about six times higher than in Sampaloc Lake (Php 6.65 m^{-2}) and Palakpakin Lake (Php 6.62 m^{-2}).

Similar to Lakes Sampaloc and Palakpakin, the variance parameters, σ^2 and γ, are found highly significant. The value of γ is 1.0 and it is concluded that all the production deviations from the frontier functions were entirely due to technical inefficiency. The factors that turned out to be highly significant determinants of technical inefficiency were farm area, depth of cage, and mortality. Moreover, the GIFT-derived dummy significantly showed higher inefficiency compared to the other strains. Nevertheless, there were only five respondents who used GIFT-derived, three for non-GIFT, one for GIFT and majority (49 of the 58 respondents) used unspecified strains and the average efficiencies of these were 28%, 59%, 17% and 39%, respectively (Table 4).

The sign of farm area is negative which means that the bigger farms are more efficient. Economies of scale can be exploited in bigger farms. Of the 58 operators, four reported cases of having more than 1000 m^2 farm area with an average efficiency estimate of 83%. The mean efficiencies of the other operators were lower, 34% for respondents having 100-500 m^2 farm area and 46% for respondents having 600-1000 m^2 farm area. However, there is a 100 m^2 restriction per cage size and a maximum limit of five cages that can be operated by an individual operator as per Municipal Ordinance 01-96 (and the case for the whole of Taal Lake). The average farm size in Laurel is 471 m^2 which means, there is not much option to improve efficiency through farm size expansion. Also, the magnitude of its coefficient only indicated a small improvement in efficiency as only a 0.01% decrease in technical inefficiency can be expected by a 10% increase in farm size.

Nevertheless, there were reports that this situation has been circumvented by some operators/financiers by registering the cages under other people's name, usually, the caretakers.

Depth of cage likewise has negative sign indicating that deeper cages were more efficient. As shown also in Table 4**,** the majority of the cages (84%, represented by unspecified strain group) have an average cage depth of 9.49 m, the five cases of GIFT-derived averaged 10.6 m, and the three cases of non-GIFT averaged 9.33 m. However, these are relatively much deeper compared to the average cage depths in Sampaloc Lake (6.2 m) and Palakpakin Lake (5.01 m). As in the case of farm size, not much can be exploited from depth in improving efficiency as only 1.3% decrease in technical inefficiency can be achieved from a 10% increase in yield. Furthermore, the extent to which the depth of the cage can be extended is governed by the transparency of the water relative to light penetration. For depths where photosynthesis cannot occur will just translate into capital wastes as the fish will not stay in those areas, more so, exposing more parts of nets to damage down below when water is turbulent especially during typhoons.

Mortality has the expected positive sign indicating that higher mortalities lead to higher inefficiency. The average mortality rates of the four groups were very high: GIFT (73.8%), GIFT-derived (82.8%), non-GIFT (93.8%), and unspecified (81.2%). Despite these high mortality rates, the effective stocking densities remained to be relatively high compared to Lakes Sampaloc and Palakpakin. To achieve the desired high effective stocking densities in Laurel, the operators engaged in very high initial stocking densities to compensate for the expected/anticipated high mortality rates. This was even made possible by the lower price acquisition of fingerlings in Laurel which averaged Php 0.32/fingerling compared to Php 0.71 pc^{-1} and Php 0.58 pc^{-1} in Lakes Sampaloc and Palakpakin, respectively. The average fingerling prices by strain groups in Laurel were not significantly different: GIFT (Php 0.30 pc^{-1}), GIFT-derived (Php 0.37 pc^{-1}), non-GIFT (Php 0.35 pc^{-1}) and unspecified (Php 0.31 pc^{-1}). Nevertheless, the coefficient of mortality indicated only a very low 0.01% decrease in technical inefficiency for every 10% increase in stocking density. The very high initial stocking rates which eventually were significantly reduced by very high mortality rates from the stocking to harvesting could explain the non-significance of stocking density in the frontier production function and the significance of mortality in the technical inefficiency function. It is quite apparent that there is a big challenge for breeders to develop fast growth strains with high survival rates.

Agoncillo

The results of Agoncillo were relatively similar with that of Laurel but with more significant factors. In the frontier production function, stocking density, feeding rate and capital turned out to be significant determinants of yield. Moreover, farm area, years of schooling and mortality were the significant factors affecting technical inefficiency (Table 2). However, there were no significant differences in the efficiency levels among the four strain groups. As in the case of Laurel, the γ was highly significant with a value of 1.0 and all of the production deviations from the frontier functions were attributed entirely on technical inefficiency**.**

Contrary to expectation, all the coefficients of stocking density, feeding rate and capital have negative signs indicating the inverse relationships with yield. The average stocking densities in Agoncillo were 907.4 fingerlings m^{-2}, 758.3 fingerlings m^{-2}, 1,333.3 fingerlings m^{-2} and 1000 fingerlings m^{-2} for the unspecified, GIFT-derived, non-GIFT and GIFT, respectively. This can probably be explained by the negative effect of overcrowding which in turn resulted to higher mortalities. In the case of Laurel, stocking density did not turn out to be significant despite the relatively the same high stocking densities and mortalities with that of Agoncillo. The difference in the results could be due to some environmental differences in location which were not captured in the model. In relation to this, feeding rate contributed negatively to yield. While that the average feeding rates for Agoncillo (0.13 m^{-2}) was relatively higher than the other three study areas, Laurel (0.08 kg

m^{-2}), Sampaloc Lake (0.09 kg m^{-2}), and Palakpakin (0.09 kg m^{-2}), the negative effect was quite perflexing.

As in the case of Laurel, it is difficult to draw a logical explanation to the negative effect of capital on yield. The average capital cost in Agoncillo (Php 32.04 m^2) was relatively close to that of Laurel (Php 36.73).

Table 4. Maximum-likelihood estimates of the stochastic frontier production and technical inefficiency model for tilapia cage operation in Laurel and Agoncillo, Taal Lake, Batangas.

Variables	Para-meters	Laurel (n=58)			Agoncillo (n=66)		
		MLE Estimates	Standard Error	t-ratio	MLE Estimates	Standard Error	t-ratio
Stochastic Frontier							
Constant	β_0	3.979	0.916	4.346	6.124	1.050	5.834
Ln X_1 (stocking density)	β_1	0.122	0.247	0.493	-1.096	0.277	-3.955**
Ln X_2 (feeding rate)	β_2	-1.006	0.511	-1.969	-2.034	0.918	-2.216**
Ln X_3 (labor)	β_3	-0.822	0.549	-1.497	1.272	0.791	1.609
Ln X_4 (capital)	β_4	-3.100	0.747	-4.153**	-1.760	0.492	-3.580**
Ln X_5 (Ln X_1 x Ln X_2)	β_5	0.104	0.083	1.251	-0.014	0.117	-0.118
Ln X_6 (Ln X_1 x Ln X_3)	β_6	0.512	0.094	5.463	-0.113	0.092	-1.226
Ln X_7 (Ln X_1 x Ln X_4)	β_7	0.491	0.094	5.209	0.464	0.087	5.232
Ln X_8 (Ln X_2 x Ln X_3)	β_8	0.186	0.082	2.264	-0.019	0.118	-0.162
Ln X_9 (Ln X_2 x Ln X_4)	β_9	0.178	0.110	1.620	0.502	0.142	3.547
Ln X_{10} (Ln X_3 x Ln X_4)	β_{10}	-0.062	0.081	-7.389	-0.188	0.199	-0.948
Technical Inefficiency Model							
Constant	δ_0	2.691	1.156	2.327	1.533	0.992	1.545
Z_1 (farm area)	δ_1	-0.001	0.000	-5.993**	0.004	0.001	2.862**
Z_2 (age)	δ_2	0.001	0.012	0.107	-0.002	0.015	-0.121
Z_3 (years in school)	δ_3	0.006	0.046	0.136	-0.144	0.064	-2.236**
Z_4 (depth of cage)	δ_4	-0.128	0.043	-2.985**	-0.002	0.057	-0.034
Z_5 (prce of fingerling)	δ_5	-0.881	0.810	-1.088	-0.109	0.127	-0.859
Z_6 (mortality)	δ_6	0.001	0.000	10.541**	0.001	0.000	2.769**
Z_7 (years of experience)	δ_7	-0.026	0.021	-1.209	-0.012	0.036	-0.331
Z_8 (culture period)	δ_8	-0.072	0.066	-1.081	-0.180	0.120	-1.504
Z_9 (dummy for GIFT)	δ_9	0.634	0.788	0.804	0.996	0.899	1.108
Z_{10} (dummy for GIFT-derived)	δ_{10}	0.698	0.206	3.383**	-0.468	0.445	-1.052
Z_{11} (dummy for non-GIFT)	δ_{11}	-0.761	0.544	-1.399	-0.306	0.862	-0.356
Z_{12} (dummy for owner-operator)	δ_{12}	0.035	0.304	0.114	0.374	0.305	1.228
Variance Parameters							
Sigma-squared	σ^2	0.345	0.048	7.255	0.353	0.110	3.205
Gamma	γ	1.000	0.003	290	1.000	0.000	27053767
Log-likelihood value				-39.619			-62.843
Mean Technical Efficiency index				0.3909			0.4636

*significant at α=5%
**significant at α=1%

In the technical inefficiency function, unlike in Laurel, the sign of farm area is positive, which means, the bigger the farm size, the higher the technical inefficiency. In Agoncillo, of the 66 respondents, 50 used unspecified strains, 13 used GIFT-derived, three for non-GIFT and one used GIFT with the average farm sizes of 204 m^2, 266.7 m^2, 233.3 m^2, and 200 m^2, respectively (Table 4). Basically, the average number of cages being operated is just less than three units. Even with the very low contribution to inefficiency of 0.004% for every one m^2 increase in farm size, the result indicated that it is not efficient to further expand farm sizes.

As in the case of Laurel, mortality has a positive sign indicating a direct relation with technical inefficiency. However, despite the very high mortality rates in Agoncillo: unspecified (82.4%), GIFT-derived (80.9%), non-GIFT (92,5%), and GIFT (92%) as presented in Table 4, since the stocking densities were also very high, the resulting effective stocking densities were still high: 137.9 pcs/ m^2, 119.9 pcs/ m^2, 111.3 pcs/ m^2 and 80 pcs/ m^2, respectively. While the fingerling prices of the GIFT (Php 0.35/pc), GIFT-derived (Php 0.38/pc), and non-GFT (Php 0.33/pc) were similarly low with Laurel (compared to Lakes Sampaloc and Palakpakin), the price of unspecified strains were relatively high (Php 0.88/pc).

As expected, years of schooling has a negative coefficient indicating that the longer years spent in school or the more efficient the fish farmers were in their operation. The average years of schooling by all 66 respondents is 8.68 years ranging from 8.33 years to 10 years among the respondents by strain groups. This means that on the average, all the respondents have finished elementary and reached high school.

CONCLUSION

The study aimed to assess the technical efficiencies of the GIFT and GIFT-derived strains versus other tilapia strains cultured in four different locations in Laguna and Batangas, namely: Sampaloc Lake, Palakpakin Lake, Laurel and Agoncillo. Technical frontier production function was run to estimate the technical efficiencies. Results showed that mean technical efficiencies of the four study areas were relatively low, though the technical efficiencies of locations in Batangas, 39.1% in Laurel and 46.4% in Agoncillo, are higher than of the locations in Laguna, 18.3% for Sampaloc Lake and 28.02 for Palakpakin Lake.

Regardless of strains, one thing was common in all four study areas. Deviations from the frontier production functions were all practically due to technical inefficiency. Thus, the strategy to improve their productivity is to address the factors that have been identified in their respective technical inefficiency functions. Mortality was the common statistically significant factor causing technical inefficiency in all four study areas. Increase in yield need not only come from additional stocking but even from reductions in the current stocking densities particularly in Laurel and Agoncillo if survival rates would improve significantly.

The low adoption of GIFT and GIFT-derived strains in the four areas covered in this study has limited the intent of the ex-post assessment of these technologies at the farm level. Majority (61% - 90%) of the sample respondents in the study areas used the non-GIFT and unspecified strains, particularly the latter. Only one respondent each in Palakpakin Lake, Laurel and Agoncillo used GIFT and none in Sampaloc Lake. Users of GIFT-derived were also relatively few especially in Laurel (9%). On the positive note, the findings provide big challenges to reassess the effectiveness of the breeding programs by the concerned institutions on where they have failed in the dissemination of this technology.

One inherent weakness of comparing the performances of the various tilapia strains at the farm level as have been illustrated in this study is the strong reliance on the fish farmers to identify tilapia strains that they have raised. On the one hand, they themselves also just rely on what their sources tell them, usually middlemen or numerous small hatcheries which in turn also rely on their sources of breeders who may also have their own problems on the proper identity and quality of their breeders. On the other hand, the individual groupings themselves further consist of several strains which rendered the results of comparisons nonspecific. The pragmatic approach may require people who will/can actually identify the tilapia strains being used by the fish farmers. It is also strongly recommended, to effectively minimize, if not eliminate, errors/discrepancies and promote reliability in the data, to have a revalidation or post-analysis survey. While data cleaning and validation can be done immediately in the field during the survey period for purposes of completing, correcting or clarifying inconsistent responses, finer details can be clarified after the analysis, whenever needed, to immediately correct any mistake and come up with more reliable results.

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