Economics of aquaculture feeding practices: Thailand

Pongpat Boonchuwong, Kulapa Boonchuwong and Kelwalin Noorit
Fisheries Economic Division
Department of Fisheries, Bangkok
Thailand

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SUMMARY

The general objective of the study is to assess the economic implications of adopting various feeding practices in aquaculture production in Thailand. The case study provides a comparative analysis of three different categories of feeding systems/practices as applied in catfish aquaculture; namely: (1) traditional; (2) semi-intensive; and (3) intensive. The study covers analysis using input output economic models relating net profit to economic variables (e.g. input and output prices) and production function/regression analysis to test the validity and inter-relationship between costs and non-economic variables under different farming system (e.g. recovery rate, stocking rates and quantity of feeds).

The principal species grown comprise hybrid catfish (*Clarias gariepinus* x *C. macrocephalus*), largely grown on a single species crop rotation system (3 cycles per annum), with stocking densities of between 230 000 (semi-intensive) to 450 000 (intensive) fingerlings per ha.

Intensive farms consume an average of 92 160 kg of feed per ha per year. Semi-intensive farms on the other hand, consume 199 681 kg of feed per ha per year which is about 2.2 times more than the rate or intensity of feeding by intensive farms. For traditional farms, average feed consumption is estimated at 158 500 kg/ha/year. The consumption rate of industrial feeds was 64 903 kg/ha/year (semi-intensive farms), 92 160 kg/ha/year (intensive farms) and 2 516 kg/ha/year (traditional farms). Semi-intensive farms used poultry by-product feeds as supplementary feeds, while traditional farms primarily used poultry by-products as their main feed.

The annual average aquaculture production cost per ha was highest among intensive farms at US$55 842. This was followed by semi-intensive which incurred an average production cost per ha at US$47 460. Traditional farms recorded the lowest production cost per ha at US$33 924. As expected, the major cost item for intensive farms is the cost of feeds which was estimated at US$48 713 which represents 87 percent of the total production cost per ha. Also, among semi-intensive and traditional farms, feed costs accounted for the largest proportions of their total production costs per hectare at 81 percent and 72 percent, respectively.

The annual average gross aquaculture margin per ha was highest for intensive fish farm operators (US$40 877) compared with those of semi-intensive farms (US$17 217) and traditional farms (US$9 890).

Gross total factor productivities of 1.71, 1.31 and 1.23 were estimated for intensive, semi-intensive and traditional farms, respectively. In terms of net total factor productivity, intensive farms (0.71) and semi-intensive farms (0.31) were able to register favorable figures while traditional farms yielded a net factor productivity coefficient of 0.23. The estimated break-even prices among intensive farms were 43 percent lower than the prevailing market prices of catfish. In the case of semi-intensive farms and traditional farms, the estimated break-even prices for fish (US$0.57/kg and US$0.55/kg) were also lower than the prevailing respective market prices of US$0.75/kg and US$0.67/kg.

Intensive farms and semi-intensive farms exceeded their break-even production levels by 42 percent and 24 percent for catfish. The actual level of fish production per ha among traditional farms was 19 percent below the break-even production level. The high cost of commercially/industrially manufactured feeds has been a major concern among intensive and semi-intensive farmers. While traditional farm respondents readily recognized the importance of commercial feeding, its high cost prohibited them from purchasing these feeds. In the same manner, the high cost of feeds likewise encroached upon the buying decisions of semi-intensive farmer-respondents to utilize the optimum amounts of this feed type in their production operations. However, the results of the study show that adoption of commercial feeding has benefited intensive and semi-intensive farms in terms of higher yields.

Estimating a production function calls for accurately measured data on output and inputs. Of the seven explanatory variables in model only four, feed cost, fingerlings, labour, and survival rate, were statistically significant. Cost of fingerlings was a more powerful explanatory variable with the high partial output elasticity. Higher levels of catfish production among intensive and semi-intensive farms have been triggered by the acceptance of higher input costs. As such, their estimated coefficients, gross revenues, gross margins/income above variable costs, net returns, net returns on land, labour and capital, gross and net factor productivities were at levels that are financially sound. In addition, the break even price and production figures for both the intensive and semi-intensive farms were exceeded by the prevailing market prices.

1. INTRODUCTION

1.1 Background

Freshwater aquaculture in Thailand started a long time ago. Initially only a few species were raised, such as common carp (*Cyprinus carpio*), snakeskin gourami/sepat siam (*Trichogaster pectoralis*) and sutchi catfish (*Pangasianodon hypophthalmus*). Such cultures were operated solely on a small scale and were confined to the area around Bangkok. In the early 1950s, other species, i.e. grass carp (*Ctenopharyngodon idella*), walking catfish (*Clarias batrachus*) and snakehead murrel (*Channa striata*), were introduced and traditional fish culture extension programs were implemented. Within a short period of time, a large number of ponds were constructed. Several idle swamps were converted and operated by farmers. From 1963 onwards, fish culture rapidly developed, partially as a result of a breakthrough in artificial breeding by hormone injection. At present, more than 15 species of fish and invertebrates are cultured. The most important freshwater aquaculture species in Thailand are Nile tilapia (*Oreochromis niloticus*), hybrid catfish *(Clarias gariepinus x C. macrocephalus*), Java barb (*Barbonymus gonionotus*), sepat siam, sutchi catfish and snakehead murrel contributing nearly 86 percent in quantity and over 75 percent in value[1].

According to the latest data available (2003), freshwater fish culture amounted to 361 100 tonnes, valued at US$401 millions (US$1.00 = 32.88 Thai Baht (B). In 2003, fish from freshwater inland aquaculture were harvested from 333 537 farms that comprised a total culture area of 111 903 ha. While output from this subsector in quantity and value contributed only about 9 percent to the country's total fish production, it reflects an increasing trend over the past two decades, with an annual average increase, in the period 1977–2003, of 10.4 percent and 15.3 percent in quantity and value, respectively.

The pattern of fish culture in Thailand, either monoculture or polyculture, varies according to species raised. Monoculture is commonly practiced for carnivorous species such as hybrid catfish, walking catfish and snakehead, and other species, such as sutchi catfish, marble goby (*Oxyeleotris marmorata*) and giant freshwater prawn (*Macrobrachium rosenbergii*). Polyculture is generally practiced for raising herbivorous species, namely, Nile tilapia (*Oreochromis niloticus*), Java barb, and common (*Cyprinus carpio*) and Chinese carps.

1.2 Rationale

Aquaculture production as practiced today is represented by different types of production systems. In the history of civilization, addressing food scarcity has been directly associated with innovations in production practice/systems. Different production practices and systems co-exist with one another depending upon the level of technology that prevails. In aquaculture production, any change in the practice of feeding (e.g. from traditional/extensive to intensive feeding practice) represents a technological innovation and this is assumed to generate increases in aquaculture production and income.

On the other hand, farmers' adoption of technology such as industrially produced complete feed for aquaculture production must be justified on the basis of its financial soundness. A technology that provides reasonable financial incentives to the fish farmers will easily be adopted than technology which does not. This case study is expected to shed light on the economics of the various feeding practices in Thailand.

1.3 Objectives of the study

The general objective of the study is to assess the economic implications of adopting various feeding practices in aquaculture production in Thailand.

Specifically, this country case study is aimed at:

(i) conducting a survey of twenty (20) aquaculture farms in each of three (3) different categories or systems of feeding practices, using a pre-tested questionnaire;

(ii) processing and analysing the data to arrive at a comparative analysis of the different farm categories highlighting the following:
  a) production (including feeding) practices,
  b) Production costs (fixed investment as well as maintenance and operating cots),
  c) income (gross revenue/gross margin),
  d) production problems,
  e) returns on investments (including labour, land and capital),
  f) break-even Analyses (break-even price, break-even production),
  g) factor productivities,
  h) statistical analysis of production function, and
  i) suggestions/recommendations;

(iii) prepare a consolidated report of the case study based on the above information.

[1] Excluded are giant freshwater prawns, frogs and soft shell turtles; they contributed about 94 percent in quantity and 93 percent in value.

2. GENERAL APPROACH AND METHODOLOGY

2.1 Comparative analysis

The case study provides a comparative analysis of three different categories of feeding practices/systems; namely: (1) traditional; (2) semi-intensive; and (3) intensive. To minimize variation in terms of fish species being produced, the comparative analysis of the various feeding practices was undertaken primarily for hybrid catfish (*Clarias gariepinus* x *C. macrocephalus*) although traditional farms stocked some other species (redfin pacu, Nile tilapia, sepat siam and giant gourami) in small proportions.

In the context of the study, traditional practices refer to a feeding system where the feeds utilized in the fish farms are sourced or developed locally and are not sold or distributed commercially. Fish farms based on traditional feeding practice generally use farm-made aquafeed and/or supplementary diets consisting of mixture of locally available feed ingredients. Farms with intensive feeding practices depend largely on commercially manufactured pelleted feeds while the semi-intensive category refers to a feeding system that combines the two with at least 25 percent of either one being utilized.

2.2 Assessment indicators

The case study assesses the impacts of the various feeding practices in terms of: (i) gross margin; (ii) net margin/return; (iii) returns on investment; (iv) returns to labour, land and capital; (v) break-even price coefficients; (vi) break-even production coefficients; (vii) gross total factor productivity/benefit cost ratio (BCR); and (viii) net total productivity. The basis of estimating the above indicators shall be the cost and returns table that was developed based on a prepared questionnaire.

2.3 Sampling technique

The case study includes three representative feeding practices or systems for the hybrid catfish *(Clarias gariepinus x C. macrocephalus*) farms. Each feeding system was analyzed based on a survey of 20 replicate farms. A total of 60 fish farms represented the sample size for the country case study. The stratified random sampling (SRS) technique was utilized in selecting the individual sample farm. The SRS was directly applied on a general listing of fish farms obtained from the municipality. The complete listing was obtained from the field office of the Department of Fisheries, Thailand.

2.4 Data processing and analysis

2.4.1 Costs and returns analysis

A tabular analysis was employed to develop the cost and returns for the various feeding systems observed in the study sites. The cost and returns analysis indicated the variable cost categories including feeds, fingerlings, fertilizers, labour, gasoline and electricity. The fixed costs and capital investments were also determined. Information on gross revenues was also determined to address the objectives of the case study. A cross sectional analysis using percent changes and/or growth rates were adopted to determine the relationship of feeding practices with selected impact indicators.

2.4.2 Statistical analysis of production function

While cost and return analysis measures the success and failure of farm business (Kay and Edwards, 1994), the estimation of the production function identifies inputs that influence product yield and shows the efficiency of input use (Shang, 1981).

Three algebraic forms of the production function model were initially estimated to determine their appropriateness and explanatory/predictive power. These were the linear, quadratic, and Cobb-Douglas forms although a wider range could be considered.

The functional form of the catfish production model chosen on its explanatory power is that of an unconstrained Cobb-Douglas production function model (Wattanutchariya and Panayotou, 1982). The specified function is an acceptable representation of the underlying mechanics of the production process.

A Cobb-Douglas production function was employed to estimate the production technology of catfish farming input and output data. Catfish production function result from combining various fixed and variable inputs in a body of water. Seven explanatory variables were hypothesized to explain catfish production. The production function used to be expressed in the following general form:

$Y = f(x_1 , x_2 , x_3 , x_4 , x_5 , \ldots x_n)$

Where; Y = yield

$x_1 \ldots x_n$ = input variables

The basic Cobb-Douglas model specified is

$Y = aX_1^{b1} X_2^{b2} \ldots X_n^{bn}$

$LnY = Lna + b_1LnX_1 + b_2LnX_2 + \ldots + b_nLnX_n$

The explanatory variables (X_i) or inputs are sometimes known as target variables because they are subject to influence by the decision-maker (producer or policy-maker). The production coefficients (b_i) or exponents in the Cobb-Douglas form are the elasticities of production. The b_i terms are actually transformation ratios of the variables input used in production at different quantities.

2.5 Scope and duration of the study

The study was conducted from 15 October 2005 to 14 February 2006. Six provinces in three regions of Thailand were selected as the site of the study. A total of 60 fish farms were analyzed in the study. A total of 20 respondents were interviewed for each of the three feeding categories observed in the fish farms as shown below:

TABLE 1
Sampling locations and categories of farms

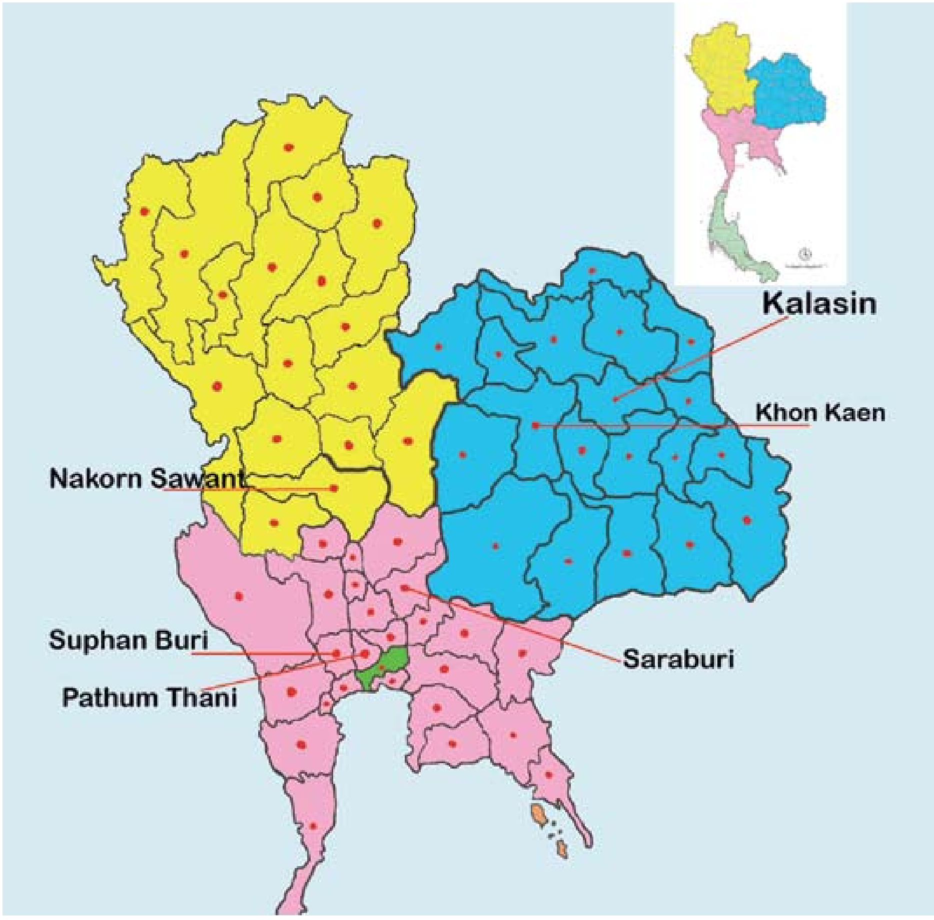
Locations and farms	No. of samples	%
Intensive farms		
Khon Kaen	1	1.67
Kalasin	19	31.67
Semi-intensive farms		
Saraburi	2	3.33
Nakorn Sawan	18	30.00
Traditional farms		
Suphan Buri	4	6.67
Pathum Thani	16	27.67
Total	60	100

3. RESULTS AND DISCUSSION

3.1 Description of the study area

Aquaculture production areas in Thailand are divided into six regions: the north, the northeast, the central plain, the east, the west and the south. Nile tilapia is the number one fish raised in every region, with the exception of the south and the central plain, where hybrid clariid catfish is the most popular species selected for culture. Study sites were selected from six provinces of Thailand (Figure 1). Three provinces are located in the Central-plain region, two provinces in the North-eastern region and one province in the Northern region. The average farm-size observed was largest in the East and the West regions, around 1.2–1.7 ha. The smallest average farm-size of 0.1 hectare was found in the south. Generally, the average size of a farm for inland aquaculture in Thailand is small, at about 0.34 ha per holding.

FIGURE 1
The study site, Thailand



3.2 Description of the respondents

Respondents have an average age of 46 years. Respondents representing semi-intensive and traditional farms have an average age of 48 years while intensive farm and traditional farms respondents are younger with an average of 45 and 46 years, respectively. All respondents from the three farm categories reported similar average household sizes of 4.6. In terms of aquaculture farming experience, semi-intensive and traditional farm respondents reported being in the profession for 9.6 and 7.7 years, respectively. Respondents using intensive feeding systems are less experienced with only 4.5 years (Table 2).

Of the total respondents in the case study, 56 (93 percent) are married and four (7 percent) are single (Table 3). Most of the respondents (77 percent) had completed primary education while a moderate percentage had completed high school (12 percent) and secondary (6 percent) education. By farm categories, those respondents engaged in intensive feeding systems were more formally educated. Fifteen percent of farmers in the intensive farm sector had completed high school education, and a further 15 percent, college education (Table 4).

The above statistics on farming experience and educational attainment appear to have a correlation with the feeding systems adopted by the respondents. The more experienced and formally educated respondents tended to practice the intensive and semi-intensive feeding systems in favor of the traditional method. These demographic characteristics may have influenced the respondents to adopt the use of commercial feeds based on their better awareness of the benefits of adopting the technology.

TABLE 2
Average age, household size, and years in fish farming by category of respondents

Category	Age	Household size	Years in farming
Intensive farms	45	4.9	4.5
Semi-intensive farms	48	3.8	9.6
Traditional farms	46	5.1	7.7
All farms	46	4.6	7.2

TABLE 3
Marital status by category of respondents

Marital status	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Married	17	85	19	95	20	100	56	93
Single	3	15	1	5	0	0	4	7
Total	20	100	20	100	20	100	60	100

TABLE 4
Educational attainment by category of respondents

Education	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Primary	13	65	18	90	15	75	46	77
Secondary	1	5	0	0	2	10	3	5
High school	3	15	2	10	2	10	7	12
College and higher	3	15	0	0	1	5	4	6
Total	20	100	20	100	20	100	60	100

On the average, 71 percent of the respondents claim that fish farming was their major occupation while 23 percent of the respondents were engaged in agriculture, 6 percent were engaged in other activities (fish trading, business and domestic acivities). All respondents from the intensive farming category reported that it was their major occupation while 85 percent and 30 percent of the respondents from semi-intensive and traditional farming categories claimed that fish farming was their major sources of income (Table 5).

TABLE 5
Major occupation by category of respondents

Occupation	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Fish farming	20	100	17	85	6	30	43	71
Fish trading	0	0	1	5	0	0	1	2
Agriculture	0	0	0	0	14	70	14	23
Business	0	0	1	5	0	0	1	2
Housewife	0	0	1	5	0	0	1	2
Total	20	100	20	100	20	100	60	100

3.3 General profile of the farm

The average size of aquaculture farm was estimated at 0.95 hectares. Semi-intensive farms were generally big farms with an average of 1.19 hectares while intensive farms recorded an average size of 0.96 hectares. Traditional farms had the lowest average size of 0.68 hectares. Intensive, semi-intensive, and traditional farms operated on an average number of 9, 6 and 3 ponds respectively with an average area of 0.11, 0.20, and 0.20 hectares per pond. The overall average water depth in the aquaculture farms was 1.82 and 1.58 meters during the dry and wet season cropping, correspondingly (Table 6).

TABLE 6
Number and area of the ponds, and water depth by category of respondents

Items	Intensive	Semi-intensive	Traditional	All categories
Total number of ponds	9.00	6.10	3.35	6.15
Total area of ponds (ha)	0.96	1.19	0.68	0.95
Average area of ponds (ha)	0.11	0.20	0.20	0.15
Rainy season	1.80	1.90	1.76	1.82
Dry season	1.50	1.72	1.52	1.58

About 78 percent of the respondents were single fish pond owners while about 22 percent were single lessees. Statistics on pond ownership indicated that all the respondents from the semi-intensive and intensive farm categories were single owners of the fish farms while only 35 percent of the traditional farmers owned their ponds (Table 7). The average duration of the contract for the ponds leased by the traditional farmers is 12 months. This information may imply that traditional fish farmer-respondents were less well-off compared with the intensive and intensive farmer-respondents. This may have affected their decision to choose the type of aquaculture feeding system based on their respective financial capacity.

TABLE 7
Type of pond ownership by category of respondents

Pond ownership	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Single ownership	20	100	20	100	7	35	47	78
Singly leased	0	0	0	0	13	65	13	22
Total	20	100	20	100	20	100	60	100

Pond operations were being used by all the farmers strictly for fish production. The decision of the respondents to engage in aquaculture production was largely influenced by their perceived profitability as cited by all of the respondents. It is widely known among the fish farm operators that sound knowledge of the aquaculture technology coupled with favorable weather conditions and output prices provided huge returns to investments (Table 8).

TABLE 8
Main factors considered in undertaking fish farming by category of respondents

Factor	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Profitability	20	100	20	100	20	100	60	100
Own consumption	-	-	-	-	-	-	-	-
Total	20	100	20	100	20	100	60	100

3.4 Farm production practices

3.4.1 Stocking strategies

The survey revealed that the majority (74 percent) of the respondents undertook crop rotation (three harvest cycles) using single specie while 13 percent had opted for a monoculture system and 23 percent for polyculture. Crop rotation was practiced by all intensive and semi-intensive farmers. Only 20 percent of traditional farmers resorted to crop rotation (Table 9).

TABLE 9
Aquaculture practices by category of respondents

Aquaculture practices	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Monoculture	-	-	-	-	8	40	8	13
Polyculture	-	-	-	-	8	40	8	13
Crop rotation	20	100	20	100	4	20	44	74
Total	20	100	20	100	20	100	60	100

The average culture period observed by all the respondents was 111 days. However, the culture period varied between the species from 107 days to 150 days (Table 10). Culture periods were also shorter for intensive and semi-intensive farmers.

TABLE 10
Average culture period (days) by type of species and category of respondents

Species	Intensive	Semi-intensive	Traditional	All categories
Hybrid catfish (*Clarias gariepinus* **x** *C. macrocephalus*)	100	95	127	107
Redfin pacu (*Colossoma macropomum)*		-	170	170
Nile tilapia (*Oreochromis niloticus*)		-	150	150
Sepat siam/snakeskin gourami (*Trichogaster pectoralis*)		-	150	150
Giant gourami (*Osphronemus goramy*)		-	150	150
All species	100	95	139	111

The average stocking rate per hectare per crop (the first crop) for hybrid catfish varied from 231 302 pieces for semi-intensive farms to 266 198 and 453 546 pieces for traditional and intensive aquaculture farms, respectively. The overall average of all catfish farms has been pegged at 309 949 pieces (Table 11).

TABLE 11
Average stocking rate (no. per hectare) and stocking size (length in cm) by species and category of respondents

Item	Intensive	Semi-intensive	Traditional
Hybrid catfish			
Stocking rate	453 546	231 302	266 198
Stocking size	2.00	4.53	3.60
Redfin pacu			
Stocking rate	-	-	438
Stocking size	-	-	2.00
Nile tilapia			
Stocking rate	-	-	1 406
Stocking size	-	-	3.00
Sepat siam			
Stocking rate	-	-	13 281
Stocking size	-	-	1.33
Giant gourami			
Stocking rate	-	-	885
Stocking size	-	-	3.00

Stocking sizes for catfish species were determined based only on the length since the respondents failed to account for their weights as payments were made based on the length and not on the weight of the fry/fingerlings. For catfish, the stocking sizes of the fingerlings are reported at 4.53 and 3.60 centimeters long for semi-intensive and traditional farms and 2.00 centimeters long for intensive farms. For catfish farms, the average stocking size of 3.38 centimeters has been a general practice for all farm categories.

3.4.2 Feeding practice

Type of feeds

Farmers used two different types of feeds, namely; (i) industrial or commercial feeds and (ii) poultry by-products (chicken). Industrial feeds were generally used for all fish consumption during the rearing period and were the most expensive type of feed at between US$1.37–2.13 (45–70 baht[2]) per kg. Poultry by-products were considered as supplementary feeds in semi-intensive and traditional farms (catfish, sepat siam) and were moderately priced at about 7 baht per kg. Poultry feed was used during the "grow-out" period. However, industrial feeds were used for intensive farms during the "grow-out" period which cost about 16–30 baht per kg , less than the feed price in rearing period.

All semi-intensive and intensive farmers used commercial/industrial feeds in catfish production Poultry by–products were used as the main feed item for traditional farms. All semi-intensive farms provided their fish species with poultry by-products as supplementary feed. The strategy to use poultry by-products as part of their feeding systems was reportedly a safety measure among semi-intensive farmers in case they are unable to finance the high cost of commercial feeds during the production period. Industrial feed is a floating feed, while poultry by-products is a fast-sinking feed.

TABLE 12
Type of feed used by category of respondents

Feed type	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Industrial feeds[1]	20	100	18	90	-	-	38	63
Poultry by-products and rice bran[2]	-	-	2	10	20	100	22	37

[1]Feed used for catfish, redfin pacu, Nile tilapia, sepat siam and giant gourami
[2]Feed used for catfish and sepat siam

Table 13 indicates that all intensive farms utilized industrial commercial feeds strictly for the rearing of fingerling while 40 percent of the respondents claimed that commercial feeds were used for both the rearing and "grow-out" periods of fish production. Among semi-intensive farms, most of the respondents reported that commercial feeds were intended for both the rearing and "grow-out" periods of their operation.

TABLE 13
Type of feeds used at different stages of rearing by category of respondents

Type of feeds used/stage of rearing	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
1. Industrial feeds[1]								
a. Rearing of fingerling	-	100	-	-	20	100	20	33
b. Rearing of fingerling & on-growing/ grow-out	20	-	20	100	-	-	40	67
2. Poultry by-products and rice bran[2]								
a. On-growing/grow-out	-	-	20	100	20	100	40	67

[1] feeds used for catfish, redfin pacu, Nile tilapia, sepat siam and giant gourami
[2] feeds used for catfish and sepat siam

[2] US$1.00 = B32.88

Frequency and intensity of feeding

The most widely practiced frequency of feeding of industrial/commercial feed was "once a day", as applied on intensive farms. Poultry by-products feed for traditional farms, were likewise fed once daily. In case of semi-intensive farms, both industrial feed and poultry by-products were fed twice daily during the "grow-out" period. All respondents for all three categories of farms (intensive, semi-intensive and traditional) irrespective of type of feeds (industrially manufactured pelleted feed and poultry by-products) used the broadcasting method for feeding.

Table 14 shows the average rate of feeding per hectare by type of feeds and fish farm category. Intensive farms consume an average of 92 160 kg/ha/year. Semi-intensive farms on the other hand, consume 199 681 kg/ha/year which is about 2.2 times more than the rate or intensity of feeding by intensive farms. For traditional farms, average feed consumption is estimated at 158 500 kg/ha/year. The consumption rate of industrial feeds was 92 160 kg/ha/year, 64 903 kg/ha/year and 2 516 kg/ha/year for intensive, semi-intensive and traditional farms respectively. Semi-intensive farms considered poultry by-product feeds as supplementary feeds since they relied more on commercial feeds to satisfy the feeding requirements. Traditional farmers primarily used their own home grown and used this as the main source of feed.

TABLE 14

Amount of feed used (kg/ha/year) by type of feed and by category of respondents

Type of feeds used	Intensive	Semi-intensive	Traditional	All categories
1. Industrial feeds	92 160	64 903	2 516	53 078
2. Poultry by-products	-	134 779	147 920	94 233
3. Rice bran	-	-	8 064	2 688
Total	92 160	199 681	158 500	149 999

3.4.3 Labour utilization and cost

Part time labour were normally hired during pre-stocking operations to excavate, clean and repair dikes and during post-stocking activities particularly harvesting.

Fish pond operations were able to employ an average of 1.0, 3.5 and 2.0 full time employees in traditional, semi-intensive and intensive farms, respectively. On part time basis, these farms were able to employ averages of 4.0, 3.7 and 4.0 workers respectively. The average number of casual employment generated by these farms was 3.0 workers, ranging from 3.5 workers for traditional farms to 3.6 workers for semi-intensive farms (Table 15).

TABLE 15

Average number of labour employed by category of respondents

Labour type	Intensive	Semi-intensive	Traditional	All categories
Full-time labour (no.)	2.0	3.5	1.0	2.2
Part-time labour (no.)	4.0	3.7	4.0	3.9
Total	3.0	3.6	3.5	3.1

Regardless of farm categories, the average total labour utilization per farm per ha per year was estimated at 198 man days. Of which 51 man days were hired and 147 man days were provided by the immediate members of the family. Total labour utilization was 234 man days, 221 man days and 137 man days for intensive, semi-intensive and traditional, farms respectively. However, it is also interesting to note that family labour utilization was highest for the intensive (180 man days) and semi-intensive farms (170 man days) relative to traditional farms (90 man days) (Table 16).

TABLE 16
Average quantity of labour utilized (man-days/ha) by type of operation and category of respondents

Type of operation	Intensive			Semi-intensive			Traditional			All categories		
	Hired	Family	Total	Hired	Family	Total	Hired	Family	Total	Hired	Family	Total
A. Pre-stocking												
1. Excavation	13	-	13	12	-	12	13	-	13	13	-	13
2. Cleaning	1	1	2	2	1	3	-	-	-	1	1	2
3. Dike repair/ construction	-	-	-	-	-	-	-	-	-	-		-
4.Lime application	-	2	2	-	2	2	-	-	-	-	1	1
5. Fertilizer application	-	1	1	-	1	1	-	-	-	-	1	1
6 Others	-	1	1	-	2	2	-	1	1	-	1	1
Subtotal	14	5	19	14	6	20	13	1	14	14	4	18
B. Post-stocking												
1. Feed application	-	175	175	-	164	164	-	89	89	-	143	143
4. Harvesting	40	-	40	37	-	37	33	-	33	37	-	37
Subtotal	40	175	215	37	164	201	33	89	123	37	143	180
All operations	54	180	234	51	170	221	46	90	137	51	147	198

3.5 Fish production costs

3.5.1 Capital investment

The major investment items identified during the survey included the acquisitions of water pumps, building and vehicle truck/pick-up (Table 17). This correspondingly required average investments of US$1 164, US$915 and US$654 per ha. Other minor investments included feed machinery (US$585), fish nets (US$126), balance machines (US$43) and boxes (US$18). It was revealed that traditional farms would not normally invest in buildings and incurred lesser investments in truck/pick-up (US$476) as compared with semi-intensive (US$654) and intensive farms (US$831).

TABLE 17
Average purchase value (US$/ha) of fixed investment by category of respondents

Cost	Intensive	Semi-intensive	Traditional	All categories
A. Buildings	1 919	20	806	915
B. Transport	831	654	476	654
C. Boxes and containers	54	-	-	18
D. Balances	45	35	50	43
E. Feed machinery	-	789	966	585
F. Net	161	120	96	126
G. Water pumps	386	1 061	2 044	1 164
Total	3 396	2 679	4 438	3 505

3.5.2 Variable costs

Variable cost items identified in the case study included the cost of labour, fry/fingerlings, feed, gasoline and electricity, and other rental costs. Variable costs were more directly related to the scale of operations at any given time.

Labour costs

On a per ha basis, traditional and intensive farms registered high labour costs of US$2 915 and US$2 654 per year, respectively. As expected, the annual labour costs incurred by semi-intensive farms, was significantly lower US$2 043 (Table 18). The proportion of costs allocated for hired labour among traditional and intensive farms were higher at about 87 percent and 75 percent, accordingly. Semi-intensive farms on the other hand, spent about 67.7 percent on hired labour as a proportion to the total cost of labour. The annual cost of labour per farm during pre-stocking operations was higher than post-stocking operations for all farms. The major cost items during the pre-stocking operations included the cost of cleaning and excavation, regardless of farm categories. During the post-stocking operations, the cost of hired labour for harvest activities was the most important labour cost item.

TABLE 18
Average annual cost (US$/ha) of human labour by type of operation and category of respondents

Type of operation	Intensive			Semi-intensive			Traditional			All categories		
	Hired	Family	Total	Hired	Family	Total	Hired	Family	Total	Hired	Family	Total
A. Pre-stocking												
1. Excavation	1 251	0	1 251	906	0	906	2 167	0	2 167	1 441	0	1 441
2. Cleaning	92	11	103	89	50	139	81	1	82	87	21	108
3. Lime application	0	5	5	0	7	7	0	1	1	0	5	5
4. Fertilizer application	0	3	3	0	4	4	0	1	1	0	2	2
5. Others	0	5	5	0	4	4	0	1	1	0	3	3
Subtotal	1 343	24	1 367	995	65	1 060	2 248	4	2 252	1 528	31	1 559
B. Post-stocking												
1. Feed application	0	629	629	0	595	595	0	389	389	0	538	538
2. Harvesting	558	0	558	323	0	323	91	0	91	324	0	324
3. Others	100	0	100	65	0	65	183	0	183	116	0	116
Subtotal	658	629	1 287	388	595	983	274	389	663	440	538	978
All operations	2 001	653	2 654	1 383	660	2 043	2 522	393	2 915	1 968	569	2 537

Cost of stocking

Regardless of farm category, the annual average cost of stocking per ha was US$2 851 of which 99 percent was paid for catfish fingerlings. Traditional farms incurred the largest annual stock acquisition cost of US$3 229 compared with semi-intensive farms (US$2 786/ha) and intensive farms (US$2 546/ha). Annual stocking costs per ha for catfish recorded the highest proportion of the total costs in all farming systems.

The cost of purchase per piece of catfish fingerlings appeared to be slightly lower for intensive farms (US$0.002/piece) relative to semi-intensive (US$0.004/piece) and traditional farms (US$0.008/piece). As claimed, cost per unit decreased as volume of purchase increases (Table 19).

Cost of feeds

The annual average cost of feeds per ha by type and fish farm category are indicated in Tables 20. It shows that intensive farms incurred huge expenditures in the purchase of feed items at US$49 947/ha/year. Semi-intensive and traditional farms correspondingly spent an annual average of US$39 258 and US$25 139 on feed. It is interesting to emphasize that among intensive farms, the total cost of acquiring commercial feeds accounted for 100 percent of the total feed cost. Among semi-intensive farms, the total cost of commercial feeds represented 71 percent of the total feed cost. These figures indicate that as the farms move from semi-intensive to intensive feeding operations, the cost of commercial feeds tends to become a major cost item. It may be argued that cash requirements become a constraining factor when a fish farmers decide to intensify his feeding system.

Miscellaneous input/other variable costs

The miscellaneous input costs associated with fish farm operations included the cost of electricity, fuel and others (Tables 21).

TABLE 19

Average annual quantity and cost (US$/ha) of stocking (fingerling) by type of species and category of respondents

Stocking/species	Intensive			Semi-intensive			Traditional			All categories		
	Number	Price/ piece	Total cost	Number	Price/ piece	Total cost	Number	Price/ piece	Total cost	Number	Price/ piece	Total cost
A. First stocking												
1. Catfish	453 546	0.002	887	231 302	0.004	1 000	266 198	0.008	2 080	317 015	0.004	1 322
2. Redfin pacu							438	0.003	1	146	0.003	0.4
3. Nile tilapia							1 406	0.005	7	469	0.005	2
4. Sepat siam							13 281	0.002	31	4 427	0.002	9
5. Giant gourami							885	0.006	6	295	0.006	2
All species	453 546	0.002	887	231 302	0.004	1 000	282 208	0.005	2 125	322 352	0.005	1 335
B. Second stocking												
1. Catfish	453 546	0.002	887	231 302	0.004	1 000	78 906	0.007	552	254 585	0.003	813
C. Third stocking												
1. Catfish	385 838	0.002	772	184 948	0.004	786	78 906	0.007	552	216 564	0.003	703
All stockings												
1. Catfish	1 292 930	0.002	2 546	647 552	0.004	2 786	424 010	0.008	3 184	788 164	0.004	2 838
2. Redfin pacu							438	0.003	1	146	0.003	0.4
3. Nile tilapia							1 406	0.005	7	469	0.005	2
4. Sepat siam							13 281	0.002	31	4 427	0.002	9
5. Giant gourami							885	0.006	6	295	0.006	2
All species	1 292 930	0.002	2 546	647 552	0.004	2 786	440 021	0.007	3 229	793 501	0.004	2 851

TABLE 20

Average annual quantity and cost (US$) of feeds by type of feeds and category of respondents, per ha

Type of feeds	Intensive			Semi-intensive			Traditional			All categories		
	Quantity (kg)	Price/ kg	Total cost	Quantity (kg)	Price/ kg	Total cost	Quantity (kg)	Price/ kg	Total cost	Quantity (kg)	Price/ kg	Total cost
A. Commercial feeds	92 160	0.542	49 947	64 903	0.431	27 983	2 516	0.415	1 046	53 078	0.487	25 859
B. Supplementary feeds												
1.Poultry by-products	-	-	-	134 779	0.084	11 276	147 920	0.154	22 833	94 233	0.119	11 304
2.Rice bran							8 064	0.156	1 260	2 688	0.156	420
Subtotal	-		-	134 779	0.084	11 276	155 984	0.154	24 093	96 921	0.121	11 724
All feed types	92 160	0.542	49 947	199 681	0.200	39 258	158 500	0.159	25 139	149 999	0.250	37 583

TABLE 21

Average annual quantity and cost (US$) of miscellaneous inputs/other variable by type and category of respondents, per hectare

Items	Intensive			Semi-intensive			Traditional			All categories		
	Quantity	Unit cost	Total cost	Quantity	Unit cost	Total cost	Quantity	Unit cost	Total cost	Quantity	Unit cost	Total cost
1. Electricity (KWH)	85	0.376	32	625	0.376	235	103	0.376	39	271	0.376	102
2. Fuel and oil	383	0.601	230	165	0.601	100	772	0.576	445	440	0.586	258
3. Others	-	-	175	-	-	671	-	-	520	-	-	453
Total	-	-	437	-	-	1 006	-	-	1 004	-	-	813

The annual average cost of electricity and fuel was estimated at US$102 and US$ 258 respectively. Cost of electricity was highest among semi-intensive farms (US$235) relative to intensive (US$32) and traditional farms (US$39). Expenses on fuel were reported by traditional, intensive and semi-intensive farms with respective annual averages of US$445, US$230 and US$100. Fuel expenses occur when farms have a larger area of operation. These are used for motorized machines and pumps.

The total average annual cost for miscellaneous input for semi-intensive, traditional and intensive farms are respectively valued at US$1 006 ha/year, US$1 004 ha/year and US$437 ha/ year.

3.6 Total production costs

The annual average aquaculture production cost per ha was highest among intensive farms at US$55 842 relative to semi-intensive (US$47 460) and traditional (US$33 924) farms. The major cost item for intensive farms is the cost of feeds which was estimated at US$48 713 representing 87 percent of the total. Among semi-intensive farms, feed cost (US$38 883) has been the major cost item accounting for 81 percent of the total. Also, the cost of feed among traditional farms (US$24 499) was likewise considered as a major cost item accounting for 72 percent of the total (Table 22). Regardless of farm categories, the cost of feeds accounted for 81 percent of the total cost while fry/ fingerling cost and labour cost represented 6 percent and 5 percent of the total cost.

For annual fixed costs which includes depreciation of asset, land cost and loan interest, fixed cost per ha was highest among semi-intensive farms at US$2 393 relative to traditional (US$1 927) and intensive (US$1 134) farms.

TABLE 22
Total cost (US$/ha) by item and category of respondents

Item	Intensive		Semi-intensive		Traditional		All categories	
	Amount/ year	%	Amount/ year	%	Amount/ year	%	Amount/ year	%
A Variable costs								
1. Labour cost	2 654	4.75	2 044	4.27	2 914	8.58	2 537	5.5
2. Fertilizer	250	0.45	314	0.66	257	0.75	274	0.6
3. Fry/fingerlings	2 546	4.59	2 786	5.78	3 229	9.59	2 851	6.2
4. Feeds	48 713	87.2	38 883	81.27	24 499	72.2	37 365	81.4
5. Miscellaneous	108	0.19	34	0.07	94	0.28	79	0.2
6. Miscellaneous input/other variable costs	437	0.78	1 006	2.95	1 004	2.96	813	2.1
Subtotal	54 708	98.0	45 067	95.0	31 997	94.3	43 919	96.0
B Fixed costs (depreciation, land & interest)	1 134	2.03	2 393	5.0	1 927	5.68	1 818	4.0
Total	55 842	100	47 460	100	33 924	100	45 737	100

3.7 Gross revenues

The average annual gross revenues per ha, was significantly higher among intensive farms (US$95 585) compared with semi-intensive (US$62 284) and traditional (US$41 887) farms. The high gross income figure among intensive farms was due to the high catfish volume 108 943 kg. The average annual catfish production for semi-intensive farms, was much lower at 82 904 kg, correspondingly. The lowest productions of catfish (60 955 kg) and other fish (1 227 kg) were recorded by traditional farms (Table 23). The high gross revenue figures among intensive and semi-intensive farms are attributed to the adoption of commercial feeding practices which resulted in more production of catfish.

3.8 Comparative analysis of economic and financial indicators

3.8.1 Gross aquaculture margins

Gross aquaculture margin is derived by deducting total variable cost of production from total gross revenue. Fixed costs are considered as sunk costs and may not be recovered in the very short-run period of at least one cropping season. As expected, intensive farms has revealed the highest returns/income above variable cost per ha per year (US$40 877) relative to semi-intensive (US$17 217) and traditional (US$9 890) farms. It is interesting to take note that all categories were able to generate positive returns to variable cost, including profitable but comparatively lower returns for traditional farming (Table 24).

3.8.2 Returns to labour, land and capital

Net returns to land, labour and capital among intensive farms yielded favorable figures of US$39 333; US$37 089 and US$39 403, correspondingly. Among semi-intensive farms, net returns to land, labour and capital are respectively estimated at US$14 364; US$12 780and US$14 556. Traditional farms, recorded low returns to land, labour and capital.

3.8.3 Gross and net total factor productivity

Gross total factor productivity (e.g. benefit cost ratio) provides a ratio of gross revenue to the total cost of production which implies that a ratio of 1.0 means that the operation is at break-even position. The gross total factor productivity of 1.71, 1.31, and 1.23 were estimated for intensive, semi-intensive and traditional farms, respectively. This indicates that the intensive farms are able to recover US$1.71 per US$1 spent while semi-intensive and traditional farms respectively generate returns of US$1.31 and US$1.23 per US$1 spent.

In terms of net total factor productivity, only intensive farms (0.71) were able to register favorable figures while semi-intensive farms (0.31) and traditional farms (0.23) yielded lower coefficients.

3.8.4 Break-even prices

For intensive farms, the estimated break-even prices of was US$0.51/kg. This estimated break-even prices are is 43 percent lower than the prevailing market price of fish. These figures imply that intensive farms can significantly absorb price changes and still achieve profitability.

TABLE 23
Annual gross revenues by harvest and species and category of respondents, per hectare (price of fish and returns are in US$)

Item	Intensive			Semi-intensive			Traditional			All categories		
	Volume (kg)	Price/kg	Total returns	Volume (kg)	Price/kg	Total returns	Volume (kg)	Price/kg	Total returns	Volume (kg)	Price/kg	Total returns
A. First harvest												
1. Catfish	38 363	0.867	33 280	29 365	0.740	21 755	35 329	0.654	23 107	34 352	0.758	26 047
2. Redfin pacu	-	-	-	-	-	-	198	1.500	297	66	1.500	99
3. Nile tilapia	-	-	-	-	-	-	587	0.850	504	196	0.850	168
4. Sepat siam	-	-	-	-	-	-	234	1.261	293	78	1.250	98
5. Giant gourami	-	-	-	-	-	-	208	2.255	469	69	2.250	156
All species	38 363	0.867	33 280	29 365	0.740	21 755	36 556	0.675	24 670	34 761	0.764	26 568
B. Second harvest												
1. Catfish	38 363	0.878	33 712	29 232	0.753	22 003	12 813	0.662	8 488	26 803	0.798	21 401
C. Third harvest												
1. Catfish	32 217	0.889	28 593	24 307	0.762	18 526	12 813	0.681	8 729	23 112	0.805	18 616
All categories	108 943	0.877	95 585	82 904	0.751	62 284	62 182	0.674	41 887	84 676	0.786	66 585

TABLE 24
Summary of assessed financial and economic indicators by farm category, per hectare

Item	Intensive	Semi-intensive	Traditional	All categories
A. Total cost (US$)[1]	55 842	47 460	33 924	45 737
B. Total variable cost (US$)[2]	54 708	45 067	31 997	43 919
C. Total fixed cost (US$)[3]	1 134	2 393	1 927	1 818
D. Total gross revenue (US$)[4]	95 585	62 284	41 887	66 585
E. Gross margin (US$)[5]	40 877	17 217	9 890	22 666
F. Net margin/returns (US$)[6]	39 743	14 824	7 963	20 848
G. Net returns to land (US$)[7]	39 333	14 364	7 829	20 513
H. Net returns to labour (US$)[8]	37 089	12 780	5 049	18 311
I. Net returns to capital (US$)[9]	39 403	14 556	7 519	20 497
J. Gross total factor productivity/benefit cost ratio[10]	1.71	1.31	1.23	1.46
K. Net total factor productivity[11]	0.71	0.31	0.23	0.46
L. Break-even price (US$)[12]	0.51	0.57	0.55	0.54
Average actual market prices (US$)	0.88	0.75	0.67	0.79
M. Break - even production (kg)[13]	63 457	63 280	50 633	57 895
Average actual production level (kg)	108 943	82 904	62 182	84 676
N. Survival rate (%)[14]	64	54	62	61

[1]Total costs = variable costs + fixed costs
[2]Sum of costs of fertilizer, feeds, fingerlings, hired and family labour, electricity, and other variable costs
[3]Sum of fees, lease, interest, rental, depreciation
[4]Value of total aquaculture outputs
[5]Gross revenue less total variable costs
[6]Total gross revenue less total cost
[7]Net margin/returns less land rent payment
[8]Net margin/returns less cost of labour
[9]Net margin/returns less 10 percent of fixed investments
[10]Gross revenue divided by total costs
[11]Net margin/return divided by total costs
[12]Total cost divided by total production
[13]Total cost divided by average price
[14]Number of pieces during harvest/number of pieces during stocking

In the case of semi-intensive farms, the estimated break-even price for fish (US$0.57/kg) are is also lower than the prevailing respective market price of US$0.75/kg. Specifically, the estimated break-even price prices is 24 percent lower than the prevailing market price.

Traditional farms require break-even prices for catfish at US$0.55. The estimated break-even price has already exceeded the prevailing market price (US$0.67/kg) by 18 percent.

3.8.5 Break-even production

A major basis in evaluating the soundness of a business operation such as aquaculture production is to determine their levels of production in relation to their break-even production levels. Break-even production level considers the farm's total production cost in relation to the prevailing output prices.

As shown in Table 24, the average break-even production for all farm categories is estimated at 57 895 kg/ha/year. Given their over-all current performance, aquaculture production exceeded their break-even production level by 32 percent for catfish. These results suggest that regardless of farm category, current farm productivity levels are significantly high enough for a sound aquaculture business in relation to their production costs and prevailing output prices.

By farm category, the respective break-even farm production levels of intensive, semi-intensive and traditional systems are pegged at 63 457 kg/ha/year, 63 280 kg/ha/year, and 50 633 kg/ha/year, respectively. The study revealed that the current fish production performances by intensive, semi-intensive and traditional farms exceeded their respective break-even production levels by 42 percent, 24 percent and 19 percent. The break-even analysis on production level implies that higher yields are a function of improved commercial feeding intensities.

3.9 Production problems

3.9.1 Enabling production factors

The fish farm respondents cited improvement in water quality (37 percent), better management (33 percent) and disease control (33 percent) as the most important factors that need to be addressed to increase production (Table 25). It is interesting to point out that majority of semi-intensive farm-respondents (45 percent) were aware that they needed to engage in commercial feeding in order to increase their farm yields. Intensive farmers (60 percent) and traditional farmers (35 percent) still feel that their improved water quality needed to be addressed in order to achieve higher yields.

TABLE 25
Enabling factors to increase production by category of respondents

Enabling factor*	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
More commercial feed	1	5	9	45	4	20	14	23
High stocking density	1	5	7	35	3	15	11	18
Quality of fry	1	5	2	10	1	5	4	7
Better management	11	55	4	20	5	25	20	33
Disease control	12	60	3	15	5	25	20	33
Improved water quality	12	60	3	15	7	35	22	37

*Multiple response

3.9.2 Disabling production factors

Limited knowledge and water quality was cited as major constraint among intensive farmers (40 percent) to improve production. Lack of capital has been a major constraint among semi-intensive farmers (15 percent) which is perhaps the principal reason why they do not fully engage in commercial feeding practices. In the case of traditional farms, limited feed availability has been a concern to allow for an improvement in production (35 percent) (Table 26).

TABLE 26
Disabling factors to increase production by category of respondents

Disabling factor	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Lack of capital	3	15	3	15	-	-	6	10
Limited feed availability	-	-	-	-	7	35	7	12
Poor market facility	2	10	1	5	5	25	8	13
Limited knowledge	4	20	-	-	-	-	4	7
Poor water quality	4	20	-	-	-	-	4	7
Limited feed availability	-	-	1	5	3	15	4	7
Others	-	-	-	-	3	15	3	5

3.9.3 Other problems

The high cost of feeds has been a major concern among fish farms (Table 27). Also, feed availability has been an important problem for all farms (Tables 28–31).

TABLE 27
Problems concerning industrially manufactured pelleted feeds by category of respondents

Problems	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Procurement	10	50	-	-	1	5	11	18
Availability	7	35	1	5	5	25	13	22
High price	19	95	15	75	19	95	53	88
Others	-	-	-	-	1	5	1	2

Unstable market prices for catfish were reported as a major concern by 85 percent of the respondents. This problem is more pronounced among intensive farms (100 percent) since they have to sell relatively larger volumes of harvested fish crops in the market at one time. Respectively, about 80 and 75 percent of the semi-intensive and traditional farmer-respondents claimed that unstable market prices have been their concern (Table 31). Since production decisions (e.g. investment decisions) are made based on the market prices, any downward fluctuation in the market would affect the profitability/viability of aquaculture business.

TABLE 28
Problems concerning farm-made feed by category of respondents

Problems	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Procurement	-	-	3	15	5	25	8	13
Availability	-	-	9	45	12	60	21	35
High price	-	-	4	20	15	75	19	32

TABLE 29
Problems concerning supplementary feed ingredients by category of respondents

Problems	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Procurement	-	-	1	5	3	15	4	7
Availability	-	-	8	40	7	35	15	25
High price	-	-	5	25	10	50	15	25

TABLE 30
Fingerling related problems concerning by category of respondents

Problems	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Procurement	8	40	1	5	2	10	11	18
Availability	14	70	2	10	2	10	18	30
High price	19	95	4	20	6	30	29	48
Others	-	-	-	-	2	10	2	3

TABLE 31
Problems concerning marketing of fish by category of respondents

Problems	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Transportation	-	-	1	5	-	-	1	2
Unstable market price	20	100	16	80	15	75	51	85
Very few traders	3	15	-	-	-	-	3	5
Others	5	25	1	5	1	5	7	12

3.10 Statistical analysis of catfish production

3.10.1 Catfish production function model

A Cobb-Douglas production function was employed to estimate the production technology of catfish farming. Input and output data of 60 farms were used. The catfish production function portrays the effects of combining various fixed and variable inputs in a body of water. Seven explanatory variables were hypothesized to explain catfish production. The production function used to be expressed in the following general form:

$Y = f(x_1, x_2, x_3, x_4, x_5, x_6, x_7, D_1, D_2)$

Where; Y = yield (kg)

x_1 = cost of feed (US$)

x_2 = cost of fertilizer (US$)

x_3 = cost of fingerling (US$)

x_4 = cost of fuel (US$)

x_5 = cost of labour (US$)

x_6 = size of fingerling (cm)

x_7 = survival rate (%)

Because the type of farm management are also important in determining yield, dummy variables (D_i) were also included such that: $D_1 = 1$ and $D_2 = 0$ if farm is intensive, $D_1 = 0$ and $D_2 = 1$ if farm is semi-intensive, and $D_1 = 0$ and $D_2 = 0$ if farm is traditional.

The basic Cobb-Douglas model specified as follows;

$Y = aX_1^{b1} X_2^{b2} X_3^{b3} X_4^{b4} X_5^{b5} X_6^{b6} X_7^{b7}$

$LnY = Lna + b_1LnX_1 + b_2LnX_2 + b_3LnX_3 + b_4LnX_4 + b_5LnX_5 + b_6LnX_6 + b_7LnX_7$

The explanatory variables (X_i) or inputs are sometimes known as target variables because they are subject to influence by the decision-maker (producer or policy-maker). Of the 6 explanatory variables[3] specified in the model are within the control of producers. The production coefficients (b_i) or exponents in the Cobb-Douglas form are the elasticities of production. The b_i terms are actually transformation ratios of the variables input used in catfish production at different quantities. Depending on the need of the study, the basic model can be modified, as reported in the section on result.

The basic function was estimated on per hectare basis. Estimating a production function calls for accurately measured data on output and inputs. Faulty data have often been the source of poor fit and insignificant estimates. Recognizing the importance of accurate data, brief discussions of the variables used in estimating the production function and the problems of measurement are provided.

Total output

Total output refers to the quantities of catfish harvested (in kilograms) during the 2005 production year. This figure includes the catfish that are consumed at home, given away as gifts, and the harvester's and caretaker's shares. The total output, therefore, reflects all marketed as well as non-marketed fish harvested from the pond.

Type of inputs

Inputs can be classified as material inputs, management inputs, and input of field work (labour). Material inputs can be further categorized as either yield-increasing inputs such as fertilizers, or yield-protecting inputs such as pesticides. Besides the material inputs, management inputs and input of field work, other inherent characteristics of

[3] There are cost of feed, cost of fertilizer, cost of fingerling, cost of fuel, cost of labour and size of fingerling

the pond environment, and/or factors affecting its environment such as pond location and weather can be employed to explain catfish output. Again, a working knowledge of these other factors can be invaluable to the catfish producer.

3.10.2 Results of the regression analysis

Production function analysis

Ordinary least squares methods were used to estimate the regression model. The main results of the estimation of the catfish production function for the whole type of management are summarized in Table 32. The estimates of the production coefficients, standard error, and coefficient of determination are also reported. The usefulness of the estimates of the various production coefficients of catfish culture is discussed to provide the reader with a more thorough understanding of the underlying input-output relationships. In general, the levels of statistical significance of the estimated production coefficients are encouraging.

One can interpret the positive production coefficients of the respective inputs as implying that an increase in output of catfish can be accomplished by increasing the intensity of input use. On the other hand, negative coefficients suggest that use of that particular input should be reduced. Of the seven explanatory variables in model only four, feed cost (X_1), fingerlings (X_3), labour (X_5), and survival rate (X_7), were statistically significant at 0.01 confidence levels. This model could explain 83 percent of the variation in yield. Cost of fingerlings was more powerful explanatory variable with the high partial output elasticity (0.4865), which indicates that 10 percent increase in cost of fingerlings (the stocking rate), holding other inputs constant, will increase yield by 4.86 percent.

Dummy variables representing type of farm management were added in model. All dummy variables were significant at the 0.01 level of confidence. This model indicates that there were differences in productivity between types of management.

TABLE 32
Estimation catfish production function (Cobb-Douglas) for Thailand

Variable	Coefficient	Standard error	t-Statistic	Probability	
a	2.5204	1.0964	2.2987	0.0257	**
X_1	0.2359	0.0679	3.4714	0.0011	**
X_2	0.0743	0.0385	1.9305	0.0592	
X_3	0.4865	0.0649	7.4956	0.0000	**
X_4	-0.0069	0.0079	-0.8760	0.3852	
X_5	0.2715	0.1022	2.6570	0.0106	**
X_6	0.0750	0.1612	0.4654	0.6436	
X_7	0.7078	0.1188	5.9571	0.0000	**
D1	0.5325	0.1638	3.2510	0.0021	**
D2	0.4375	0.1509	2.8990	0.0055	**

R-squared	0.8305	Mean dependent variable	11.1189
Adjusted R-squared	0.8000	S.D. dependent variable	0.7612
S.E. of regression	0.3404	Akaike info criterion	0.8338
Sum squared residual	5.7949	Schwarz criterion	1.1829
Log likelihood	-15.0153	F-statistic	27.2144
Durbin-Watson statistics	1.7273	Probability (F-statistic)	0.0000

**Statistically significant at 0.01 confidence levels

3.10.3 Discussion

In general, the Cobb-Douglas equation fitted the data well as indicate by the F-value and R^2. The F-values were highly significant. The R^2 values are also statistically significant.

Their occasional modest values are not unusual in multiple regression analysis using cross-sectional data. Lastly, there appear to be no problems with dominant variables or multi-co-linearity.

In this study, an estimation of the production technology of catfish culture indicated that the main factors influencing yield were: seed cost, feed cost, labour cost, and survival rate.

Because a large purpose of this study was to examine the nature of the input-output relationship and to test the significance of each of the estimates of the production coefficients, all the coefficients will be reported even though some of them are not significant as shown by their low t-values. In all cases there are sufficient degrees of freedom for statistical tests. More than 50 percent of the regression or production coefficients are significant at small probability levels. Errors due to deficient memory recall may have contributed to the presence of some insignificant coefficients.

4. CONCLUSIONS

The study reveals that adoption of commercial feeding has benefited intensive and semi-intensive farms in terms of higher yields as measured in kilograms of catfish production. Traditional farms suffered from poor production levels relative to other farms solely because they stuck to a feeding system that were less effective in improving the weights of the fish species at the time of harvest. Feed costs were a major factor amongst all the farm categories.

Higher production levels of catfish production among all categories have consequently triggered their high acceptable levels of financial and economic indicators. As such, their estimated coefficients, gross revenues, gross margins/income above variable costs, net margins/returns, net returns on land, labour and capital, gross and net factor productivities, all demonstrate strong financial and economic performance.

One of the limitations of this case study is its heavy emphasis on the financial and economic analysis of feeding systems in the study area. As expected, this study did not address the more technical aspects of adopting not only commercial feed application but also the optimum level of stocking rates. Although high weight gains and recovery rates (e.g. number of pieces recovered during harvest vis a vis stocking periods) are generally observed, this was not isolated in terms of the specific impacts that are attributable to commercial feeds and or stocking rates.

Finally, estimating a production function calls for accurately measured data on output and inputs. Of the seven explanatory variables in model only four, feed cost, fingerlings, labour, and survival rate, were statistically significant. Cost of fingerlings was a powerful explanatory variable with high partial output elasticity.

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APPENDIX

Appendix A: Observation and variables for multiple regression (catfish production function)

Observed number	Y	X_1	X_2	X_3	X_4	X_5	X_6	X_7	D_1	D_2
1	125 000	46 200	38	1 500	300	6 116	2	0.50	1	0
2	101 250	10 557	316	2 700	59	2 331	2	0.75	1	0
3	120 536	38 210	226	3 214	391	2 485	2	0.53	1	0
4	112 500	25 598	264	2 813	207	2 639	2	0.64	1	0
5	140 625	92 127	174	2 813	376	3 016	2	0.80	1	0
6	70 313	44 332	59	1 406	84	2 779	2	0.80	1	0
7	76 563	54 017	86	1 750	145	1 757	2	0.70	1	0
8	78 750	49 017	162	2 625	89	1 934	2	0.48	1	0
9	120 833	96 407	411	2 417	77	1 617	2	0.70	1	0
10	93 750	56 378	186	3 600	238	3 493	2	0.42	1	0
11	118 750	82 009	196	2 078	48	1 832	2	0.90	1	0
12	75 000	42 307	155	1 500	396	1 741	2	0.80	1	0
13	157 500	19 674	232	1 114	130	2 209	2	0.85	1	0
14	109 375	34 577	410	3 656	86	1 613	2	0.78	1	0
15	125 000	24 766	197	2 500	55	2 663	2	0.70	1	0
16	112 500	38 389	240	2 475	108	2 287	2	0.73	1	0
17	93 750	60 453	352	1 969	338	3 558	2	0.50	1	0
18	150 000	42 514	348	5 683	656	2 556	2	0.65	1	0
19	84 375	41 720	174	2 461	656	2 525	2	0.36	1	0
20	112 500	75 004	773	2 564	153	3 938	2	0.60	1	0
21	83 333	11 334	48	2 083	119	2 959	4	0.80	0	1
22	43 750	13 372	234	1 094	226	1 769	4	0.70	0	1
23	112 500	64 547	306	3 125	0	1 785	3.5	0.60	0	1
24	100 000	75 681	234	2 250	182	1 553	3.5	0.53	0	1
25	62 500	73 508	344	2 250	85	2 097	3.5	0.25	0	1
26	65 625	30 342	399	2 344	481	787	7	0.56	0	1
27	112 500	92 273	353	5 063	0	1 703	6	0.40	0	1
28	83 333	58 359	193	3 125	481	1 649	7	0.60	0	1
29	93 750	55 036	534	1 406	73	1 422	3.5	0.67	0	1
30	75 000	37 195	1 313	2 813	0	1 703	3	0.52	0	1
31	67 500	13 171	108	3 375	0	1 022	2	0.40	0	1
32	50 000	54 188	270	2 344	33	927	4	0.32	0	1
33	56 250	52 383	606	2 250	26	2 018	4	0.23	0	1
34	52 500	13 295	675	3 750	16	4 111	2.5	0.30	0	1
35	93 750	29 688	11	1 641	0	3 162	5	0.86	0	1
36	95 000	21 788	28	1 406	0	3 244	10	0.78	0	1
37	61 719	7 222	181	2 930	0	1 766	6	0.33	0	1
38	70 313	13 699	43	3 516	0	2 313	3	0.40	0	1
39	91 250	22 261	392	3 750	281	2 548	3	0.50	0	1
40	187 500	38 323	225	2 765	0	2 349	6	0.67	0	1
41	187 500	55 012	586	7 324	410	5 248	4	0.48	0	0
42	150 000	47 291	469	5 859	495	1 823	4	0.48	0	0
43	206 250	24 688	15	10 828	500	2 683	4	0.79	0	0
44	225 000	36 626	26	9 844	500	2 452	4	0.86	0	0
45	15 417	23 805	361	507	146	1 670	3	0.33	0	0
46	62 500	12 182	875	6 745	104	1 244	5	0.97	0	0
47	12 500	8 459	246	195	174	10 243	5	0.21	0	0
48	27 778	17 135	219	1 563	188	2 649	2	0.59	0	0
49	25 000	11 469	31	5 000	188	2 380	3	0.30	0	0
50	48 438	4 047	64	2 031	21	3 877	5	0.64	0	0
51	21 875	42 078	33	1 953	361	3 964	5	0.28	0	0
52	28 125	20 852	19	1 375	311	895	4	0.45	0	0
53	14 583	37 919	21	1 953	103	3 558	3	0.12	0	0
54	18 750	38 873	24	781	133	3 193	3	0.60	0	0
55	13 555	8 022	1 770	1 516	141	1 892	3	0.20	0	0
56	75 000	35 578	39	3 438	4 575	1 487	2	0.57	0	0
57	63 438	30 813	313	2 891	470	3 719	2	0.57	0	0
58	19 792	22 758	13	673	174	1 023	3	0.64	0	0
59	12 500	5 635	9	260	60	1 241	3	0.80	0	0
60	15 625	6 734	4	3 645	57	3 032	5	0.80	0	0