Economics of aquaculture feeding practices: Bangladesh

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SUMMARY

This case study was conducted to assess the economics of sutchi catfish, *Pangasianodon hypophthalmus* (locally known as pangas) monoculture in Bhaluka *upazila* (sub-district), Mymensingh, a district of north-central Bangladesh. The analysis examined three different categories of feeding practice: (1) intensive, (2) semi-intensive, and (3) traditional.

Fish farms based on traditional feeding practice use supplementary diets consisting of a mixture of locally available feed ingredients. Farms with intensive feeding practice depend solely on commercially manufactured pelleted feeds while the semi-intensive category refers to the feeding practice of using farm-made aquafeed. A total of 60 fish farms (20 from each feeding practice) were surveyed via interviews using a structured questionnaire and the Rapid Rural Appraisal method. The stratified random sampling technique was used in selecting the sample farms.

Based on the survey of 60 farmers from three different feeding practices, the average area of pangas pond was 0.23 ha, varying from 0.12 ha in traditional farms to 0.21 ha in semi-intensive and 0.36 ha in intensive farms. In general, the culture period is typically 9 to 12 months. The majority of fish farmers stocked their ponds from as early as March to May and harvested their fish at least after 3 months and the multiple stocking and the staggered harvesting were practised at similar intervals until the end of the year. The average annual stocking density of fingerlings for intensive, semi-intensive and traditional farms were estimated at 35 900, 23 575 and 12 065 per ha, respectively. On average, the quantity of feed used per ha per annum were 22 370 kg, 13 010 kg and 5 790 kg in intensive, semi-intensive and traditional feeding practices, respectively. Survey results showed that almost all intensive and semi-intensive farmers used fertilizers (mainly cow dung, urea and triple super phosphate) at varying frequencies and rates. The highest average annual production of pangas per ha was calculated in intensive farming (13 945 kg), as compared with semi-intensive (7 705 kg), and traditional (3 380 kg). The difference in fish yields was attributed to the differences in farm size, feed and seed inputs as well as management skill.

Feed costs generally constitute the highest single operational cost, accounting for 76 percent, 69 percent and 59 percent of total costs in intensive, semi-intensive and traditional feeding practices, respectively. Although all farmers in the three different feeding practices made profits, considerable variation in production costs and profitability was observed in the different feeding practices. The total costs of pangas farming of all sample farmers averaged US$2 964 per ha per year, varying from US$5 217 in intensive farming to US$2 694 in semi-intensive and US$981 in traditional farming. Despite higher production costs per ha, the average annual net return was higher in intensive farming (US$3 364) compared with semi-intensive (US$2 048) and traditional farming (US$1 099). The higher profits were as a result of higher production. The highest average gross margin per ha was found in intensive farms (US$3 649) compared with semi-intensive (US$2 235) and traditional (US$1 188) farms. The Cobb-Douglas production function model indicates that there is enough scope to increase the production and income from pangas farms in semi-intensive and traditional feeding practices by applying more seed, feed and fertilizer. However, intensive feeding exhibits decreasing return to scale.

The commercially manufactured pelleted feed is the most effective way to cultivate fish, although feed costs are extremely high. However, statistical analysis indicated that inputs are inefficiently used in intensive feeding. The highest benefit-cost ratio is found in traditional feeding at 2.12, compared with 1.76 in semi-intensive and 1.64 in intensive feeding. It is therefore suggested that the semi-intensive system may be preferable with the option of decreasing production costs by using farm-made quality feed in order to increase profits. Thus, development of feed based on low-cost locally produced ingredients would help improve farmer's declining profit margins. In addition, training and extension services would help to improve profitability and reduce risks. Most of the poor framers (traditional farmers) reported that higher production costs as well as lack of money was the most important constraint for pangas farming. Thus, adequate bank credits with low interest would provide the basis for a change in practices from traditional to semi-intensive feeding.

1. INTRODUCTION

1.1 Rationale

Aquaculture production comprises different systems depending upon the applied level of technology. 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.

Farmers' adoption of technology such as industrially produced complete feed for aquaculture production result in higher outputs, higher costs and improved financial returns. Other farmers may be constrained through factors such as a lack of capital or a lack in education, and will adopt lower cost input systems including traditional or semi intensive farming. The proposed case study is expected to shed light on the economics of the various feeding practices as applied in Bangladesh. The case study provides a comparative analysis of three different categories of feeding practices, namely: (1) intensive, (2) semi-Intensive, and (3) traditional.

1.2 Aquaculture in Bangladesh

Over the last decade, there has been a dramatic increase in inland aquaculture production, an average annual growth rate of nearly 20 percent (Muir, 2003). Around 400 000 ha of freshwater ponds and more than 900 000 households are involved in aquaculture (ADB, 2005). Conditions are highly favourable for the rapid expansion of aquaculture, as the quantity of seed produced has risen rapidly in recent years. The total fish production in Bangladesh was estimated at 2.21 million tonnes in 2004–05[1] of which 0.88 million tonnes were obtained from closed-water culture fisheries, contribution about 40 percent of the total fish production (DoF, 2006). Value added from aquaculture was estimated to total US$643 million. Pond carp polyculture accounts for 80 percent of the total freshwater aquaculture production in Bangladesh. The remaining 20 percent were mainly from pangas and tilapia culture and integrated rice-fish farming (ADB, 2005). A current focus is on promoting pangas farming with important local food supply benefits, and increasing income of the poor farmers.

With the increasing demand for food fish and the decline in capture fisheries production (currently 39 percent of the total fish production), pangas monoculture in Bangladesh is heading towards intensification. This shift from low density to high density culture i.e. traditional to semi-intensive or intensive culture is consequently leading to an unprecedented rise in the demand for feeds over and above other inputs (fingerlings, fertilizers). The success of intensive and semi-intensive fish culture depends to a large extent on the application of suitable feeds. Because faster growth rates and higher returns on capital, farmers are gradually shifting from farm-made aquafeed, to industrially manufactured pelleted feed. However, the main constraints to expansion in uptake are lack of money and inadequate technical knowledge.

Sutchi catfish (*Pangasianodon hypophthalmus*) is an indigenous fish species of Thailand, living in the Mekong River (Roberts and Vidthayanon, 1991). This species is particularly important for their fast growth, lucrative size and high market demand. This species can also be stocked at a much higher density in ponds compared to other cultivable species. It was introduced in Bangladesh from Thailand in 1989 (Banglapedia, 2006) and has become an important source of food fish for the country. Pangas farming began in Bhaluka *upazila*[2], Mymensingh, in 1998.

1.3 Objectives of the study

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

Specifically, the case study is aimed at:

(i) conducting a survey of three feeding practices in sixty (60) aquaculture farms, twenty (20) per category;

(ii) processing and analysing the data to arrive at a comparative analysis of the farms highlighting the following:

a) general profile,
b) production (including feeding) practices,
c) production problems,
d) production costs (fixed investment as well as maintenance and operating costs),
e) income (gross margin and net margin/return),
f) returns on investments (labour, land and capital),
g) break-even analyses (break-even price and production), and
h) recommendations;

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

[1] Bangladesh fiscal year: 1 July –30 June

[2] An *upazila* is an administrative government unit in Bangladesh consisting of unions, each of which consists of a number of villages.

2. GENERAL APPROACH AND METHODOLOGY

2.1 Comparative analysis

To minimize variation in terms of fish species being produced, a comparative analysis of various feeding practices was undertaken for the same species in the country. The species and aquaculture system selected for Bangladesh was monoculture of sutchi catfish, *P. hypophthalmus,* henceforth referred to as pangas.

In the context of the study, traditional systems refers to a feeding practice 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 supplementary diets consisting of mixture of locally available feed ingredients such as rice bran, wheat bran or oil cake. Farms with intensive feeding practice depend solely on commercially manufactured pelleted feeds while a semi-intensive category refers to a feeding practice using on farm-made aquafeed which comprises rice bran, wheat bran, oil cake, fishmeal, flour, dried fish, oyster shell, salt and vitamins.

2.2 Assessment indicators

The case study assessed the impacts of the various feeding practices in terms of: (i) gross margin, (ii) net margin/return, (iii) benefit cost ratio (BCR), (iv) returns on investment, (v) returns to labour and land, (vi) break-even price coefficients and (vii) break-even production coefficients. The basis of estimating the above indicators were cost and earnings tables developed from the questionnaire results.

2.3 Sampling technique

The case study represent examination of three feeding practices in the three different aquaculture farm systems: traditional, semi intensive and intensive. A total of 60 fish farms were surveyed. Sample farms comprised 20 farms in each feeding practice. The selection technique of stratified random sampling[3] (SRS) was used to select the farms using the following approach:

Step 1: A listing of fish farms was collated for Bhaluka *upazila* (subdistrict), Mymensingh, derived from data provided by the Department of Fisheries (DoF) and relevant non-government organizations (NGOs).

Step 2: The country author in association with government fisheries officers and/or members of existing farmers association, identified the different farming systems used.

Step 3: From a sublisting of the categorized fish farms, 20 farms were selected at random from each category. Sixty farms were identified for analysis.

2.4 Data processing and analysis

Tabular analyses were used to develop the costs and returns tables for the various feeding practices observed in the study area. The costs and returns analysis contained the variable cost items: fingerlings, feeds, fertilizers, labour and miscellaneous. The fixed costs and capital investments such as depreciation (i.e. water pump, net and feeding machines), permanent staff salary including caretaker and guard, land use cost (or lease money) and interest on operating capital were also determined. Farm gross revenues were also identified based on farm-gate prices of harvested fish and current local market prices. A cross sectional analysis using graphs and percentage changes are used to determine the differences between the feeding practices.

[3] A stratified sample is one obtained by separating the population elements into non-overlapping groups, called strata, and then selecting a sample from each stratum (Scheaffer *et al*., 1990). Arens and Loebbecke (1981) noted that stratification is used for most common reason is that reduces the sample size needed to achieve a desired level of precision and reliability.

Multiple regression analyses using economic and bioeconomic models relating to gross revenue derived from pangas production was undertaken. Regression runs comprised the profit function related to gross revenue and input and output prices. Likewise bioeconomic models relating gross revenue with economic variables (e.g. input and output prices) and non-economic variables (e.g. stocking rates, quantity of feeds and size of ponds) were analysed to determine the existence of statistical relationships.

2.5 Scope and duration of the study

The case study was conducted for a period of four months from 15 October 2005 to 15 February 2006. A total of 60 farmers were analysed where 20 respondents were interviewed for each of the three feeding categories. General descriptions of some of the activities are indicated as follows:

2.5.1 Background information

A literature review was undertaken to establish the aquaculture feed management practices used in the country and sector's contribution to the economic development of the fishery sector in general and the aquaculture sector in particular. This section also includes a discussion on the background information of the selected area under study.

2.5.2 Rapid appraisal of the survey area

The SRS was validated using participatory rapid rural appraisal (RRA) in order to substantiate the authenticity of the farms identified for survey. This also insured consistency in the type of species produced by the respondents so as to allow meaningful comparative analysis. RRA was undertaken using local officials from the relevant government and private organizations.

2.5.3 Finalization of draft questionnaire

Part of the rapid appraisal activity was used to validate the survey questionnaire approach in six test farms; two from each feeding practice. This led to redesigning the questionnaire to suit the field conditions in the study area.

2.5.4 Field survey

The field survey of 60 farms was undertaken based on the revised questionnaire over a period of seven weeks.

2.5.5 Data processing and analysis

Collected data were coded and entered into a Microsoft Excel database. Some data were collected in local units such as *bigha*[4], *maund*[5] due to familiarity for respondents. These were converted into international units before transfer to computer. SPSS (Statistical Package for Social Science) was used to analyse the data.

2.6 Limitations/problems encountered

The following problems and difficulties were noted during the survey work:

1. A significant amount of effort had to be devoted to convincing the respondents as to the legitimacy of the survey.
2. The respondents suspected the interviewees were acting as agents for the tax office, police department or other government agency.

[4] A unit of land is equivalent to 0.13 ha in the study area.
[5] A unit of weight measure equivalent to approximately 37.4 kg.

3. Most farmers and associated groups did not keep records of income and expenditure. Even if some farmers provided financial data, this was based on their best estimates. Extra attention had to be paid to validating financial information using different data collection methods (i.e. questionnaire interviews, RRA and cross-check interviews with key informants).

The interviewers had to have on hand support from DoF fisheries inspectors before commencing the survey work.

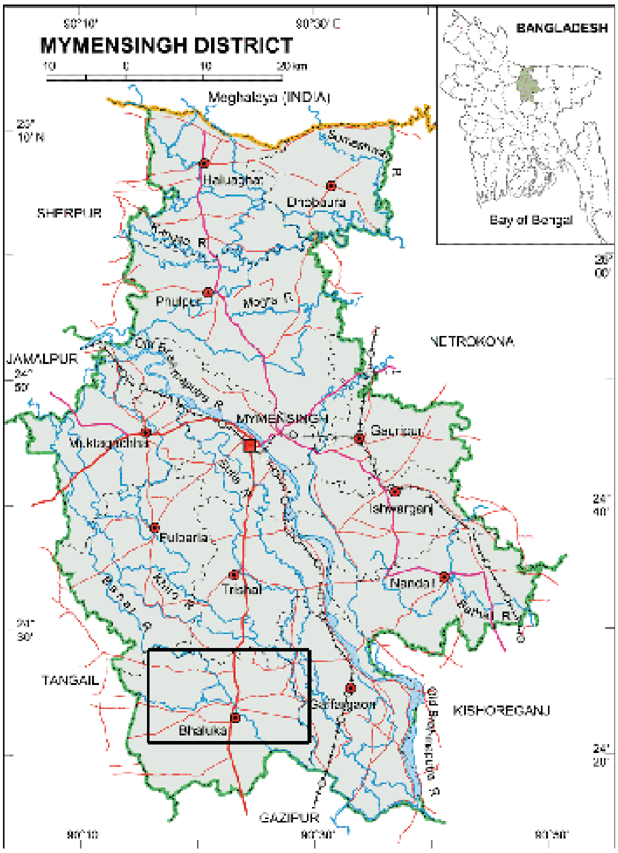
3. RESULTS AND DISCUSSION

3.1 Description of the study area

The area for the study was Bhaluka *upazila*, Mymensingh, in the north-central Bangladesh (Figure 1). Mymensingh district is divided into 12 *upazilas*[6]. Bhaluka *upazila* was selected for this study because of its importance in pangas farming. This is largely determined a combination of: the availability of hatchery-produced fry; the availability of ponds; warm climate (24 to 32°C); cheap and abundant labour. In addition, farmers in this area received training on pangas farming with the help of the Mymensingh Aquaculture Extension Project (MAEP), funded by Danish International

FIGURE 1
Map of Mymensingh District

Source: Banglapedia (2006)



[6] Mymensingh district is divided into 12 *upazilas* namely: 1) Mymensingh Sadar, 2) Trishal, 3) Bhaluka, 4) Gaffargaon, 5) Nandail, 6) Ishwarganj, 7) Gauripur, 8) Phulpur, 9) Muktagacha, 10) Phulbaria, 11) Haluaghat and 12) Dhobaura.

Development Assistance (Danida). As a result, there has been a dramatic increase in pangas production over the last few years. Carp farming[7], which represents the main freshwater aquaculture production system in Bangladesh, is not suited to this site because of the lower soil fertility.

3.2 Description of the respondents

3.2.1 Development in pangas activities

Only ten percent of farmers had started pangas farming by 1999, 27 percent in 2000, and the remaining 63 percent thereafter (Table 1). The highest number of farmers started pangas farming in 2000 as a result of MAEP training; varying from 40 percent in traditional farming to 25 percent in intensive and 15 percent in semi-intensive farming. Before pangas farming, most farmers were involved in integrated rice-fish farming, fry rearing, tilapia farming and a few were involved in carp polyculture, although this area is reported as not suitable for carp farming due to lower soil fertility.

TABLE 1
Starting year of pangas farming by category of respondents

Starting year	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
1998	1	5	0	0	1	5	2	3.3
1999	0	0	1	5	3	15	4	6.7
2000	5	25	3	15	8	40	16	26.7
2001	1	5	3	15	4	20	8	13.3
2002	5	25	7	35	3	15	15	25.0
2003	7	35	6	30	1	5	14	23.3
2004	1	5	0	0	0	0	1	1.7
Total	**20**	**100**	**20**	**100**	**20**	**100**	**60**	**100**

3.2.2 Reasons for farming pangas

The vast majority of respondents (90 percent) produced pangas for income generation, although 8.3 percent cultured for own consumption and a further 1.7 percent for availability of seed (Table 2). All intensive farmers produced pangas for income generation, compared with semi-intensive (95 percent) and traditional (75 percent) farming. It is widely known among the fish farmers that intensive pangas farming provides a high return on investment.

TABLE 2
Reasons for pangas farming by category of respondents

Reasons	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Income generation	20	100	19	95	15	75	54	90.0
Own consumption	0	0	1	5	4	20	5	8.3
Seed availability	0	0	0	0	1	5	1	1.7
Total	**20**	**100**	**20**	**100**	**20**	**100**	**60**	**100**

3.2.3 Farmer age structure

Most farmers were quite young, with an average age of 39 ranging from 29 to 50. There was very little difference in farmer's age by different culture systems (Table 3). The

[7] Popular species are indigenous Indian major carps: catla (*Catla catla*), rohu (*Labeo rohita*), and mrigal (*Cirrhinus cirrhosus*); and exotic species such as: silver carp (*Hypophthalmicthys molitrix*), grass carp (*Ctenopharyngodon idella*), and common carp (*Cyprinus carpio*).

highest percentage of farmers were found between 31 to 40 age group, semi-intensive farmers having the highest (70 percent) and intensive framers the lowest (60 percent).

TABLE 3
Distribution of pangas farmers' age group by category of respondents

Age group	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Up to 30	1	5	1	5	0	0	2	3.3
31 to 40	12	60	14	70	13	65	39	65.0
41 to 50	7	35	5	25	7	35	19	31.7
Total	20	100	20	100	20	100	60	100
Average age	40		39		38		39	

3.2.4 Gender and marital status

All interviewed farmers (head of the households) were male. Of the total (60) interviewed, 59 (98.3 percent) farmers were married and one (1.7 percent) was widowed (Table 4). Pangas farming was a male dominated activity. In general, women provided partial assistance to men in the supervision and management of ponds, particularly in applying feed, lime and fertilizers. The daily harvesting of fish for family consumption is performed by women with the help of the children. Women's activities are reported to have increased in pangas production.

TABLE 4
Marital status of the farmers by category of respondents

Marital status	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Married	19	95	20	100	20	100	59	98.3
Widowed	1	5	0	0	0	0	1	1.7
Total	20	100	20	100	20	100	60	100

3.2.5 Household size

The respondent households had an average family size of 5.9. There was little difference in this characteristic among the farmers from all the groups (Table 5). The respondents reported that all of the family members above 12 years were directly engaged in a combination of activities to supplement the household income, including: pangas farming; gardening; and poultry and livestock rearing.

TABLE 5
Distribution of farmer's family size by category of respondents

Family size	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Less than 5	2	10	0	0	1	5	3	5.0
5 to 7 persons	15	75	19	95	18	90	52	86.7
More than 7	3	15	1	5	1	5	5	8.3
Total	20	100	20	100	20	100	60	100
Average	5.8		5.9		6.0		5.9	

3.2.6 Occupation

Pangas farmers typically pursue more than one occupation to earn their livelihood. These can be classified into two groups on the basis of their relative importance (income and time spent):

1) **Main occupation:** Fifty-eight percent of respondents stated that their primary occupation was fish farming, while 26.7 percent and 15 percent were occupied in agriculture and small business activities, respectively (Table 6). The highest

percentage of farmers involvement in fish farming was noted among semi-intensive farmers (65 percent) followed by intensive (60 percent) and traditional (50 percent). On the other hand, the highest percentage of farmers involvement in agriculture was observed among traditional farmers (45 percent) compared with semi-intensive (25 percent) and intensive (10 percent) farmers.

TABLE 6
Main occupation of farmers by category of respondents

Main occupation	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Fish farming	12	60	13	65	10	50	35	58.3
Agriculture	2	10	5	25	9	45	16	26.7
Petty business	6	30	2	10	1	5	9	15.0
Total	**20**	**100**	**20**	**100**	**20**	**100**	**60**	**100**

2) **Secondary occupation:** Forty one percent of respondents stated that their secondary occupation was fish farming, while 38.3 percent, 6.7 percent, 6.7 percent, 5.0 percent and 1.7 percent were occupied in agriculture, livestock rearing, small business activity, day labouring and fish trading, respectively (Table 7). The numbers of traditional, semi-intensive and intensive farmers who consider fish farming as their secondary occupation are respectively estimated at 50 percent, 35 percent and 40 percent.

TABLE 7
Secondary occupation of fish farmers by category of respondents

Secondary occupation	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Fish farming	8	40	7	35	10	50	25	40.7
Agriculture	7	35	12	60	4	20	23	38.3
Livestock rearing	1	5	1	5	2	10	4	6.7
Petty business	3	15	0	0	1	5	4	6.7
Day labour	0	0	0	0	3	15	3	5.0
Fish trading	1	5	0	0	0	0	1	1.7
Total	**20**	**100**	**20**	**100**	**20**	**100**	**60**	**100**

3.2.7 Literacy and education

The reported literacy rate was found to be 58.3 percent. This is slightly higher than the national the average adult literacy level of 55 percent (BBS, 2002). NGOs have been working with fish farmers to improve their literacy levels. Five categories were used to define education level for pangas farmers: 1) Primary level – 1 to 5 class education, 2) Secondary level – 6 to 10 class education, 3) SSC (Secondary School Certificate) – class 10 pass, 4) HSC (Higher Secondary Certificate) – class 12 pass, and 5) Bachelors. From the total (60) interviewed, 21 (35 percent) farmers had primary level education, 9 (15 percent) had secondary, and 5 (8.3 percent) had SSC level education (Table 8). None of the farmer respondents were found to be above SSC education level. The highest number of farmers with primary, secondary and SSC level education were observed among intensive farmers, followed by semi-intensive and traditional farmers. Statistical analysis shows that farmer's education levels were significantly and positively related to feeding practices they have adopted. The results show that educated respondents tended to practice the intensive and semi-intensive feeding practices. The correlation estimated at 0.67, statistically significant at the 0.001 level.

TABLE 8
Education level of pangas farmers by category of respondents

Education level	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
No formal education	0	0	11	55	14	70	25	41.7
Primary	8	40	7	35	6	30	21	35.0
Secondary	7	35	2	10	0	0	9	15.0
SSC*	5	25	0	0	0	0	5	8.3
Total	**20**	**100**	**20**	**100**	**20**	**100**	**60**	**100**

*Secondary School Certificate examination

3.2.8 Formal training

In recent years, DoF, MAEP, NGOs, and other institutes have been providing training to the pangas farmers. In particular, the Danida-funded MAEP worked with the pangas farmers in Bhaluka *upazila* and its surrounding areas. Training and technical assistance (e.g. rearing of fry, applying feed and fertilizers, maintaining water quality and disease control) were the main components of the project. Pangas farming technology had been introduced into the area initially through MAEP. However, according to the survey, only 33.3 percent of farmers received formal training on pangas farming (Table 9). The highest percentage of farmers who got training was found among the intensive farmers (75 percent) compared with semi-intensive farmers (25 percent). None of the traditional farmers had received any training. Neighbours and friends who received training in semi-intensive production were the main source of technical assistance for the traditional farmers. The length of training varied between 2, 3 and 7 days as reported by 17 (85 percent), 2 (ten percent) and 1 (one percent) of the trained respondents (n=20), respectively. Almost all respondents who got 2 days training reported that the training was not good enough for them to raise fish with confidence.

TABLE 9
Status of formal training by category of respondents

Attendance in training	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Yes	15	75	5	25	0	0	20	33.3
No	5	25	15	75	20	100	40	66.7
Total	**20**	**100**	**20**	**100**	**20**	**100**	**60**	**100**

3.3 Farm production practices

3.3.1 Pond features

Most fish culture takes place in ponds constructed as borrow pits, which were dug out to raise the level of land for village households and roads (ADB, 2005). Thus, the ponds were not deliberately built as fishponds, but as part of excavation works used to support for village and homestead development. The majority of households, including some of the landless (i.e. no agriculture land) and most of the marginal and small-scale farmers, had ponds (Figure 2). According to the survey, most of the households (86.7 percent) have a single pond, and the remainders (13.3 percent) have two ponds (Table 10). The average area of pond is 0.23 ha. There is a significant difference

FIGURE 2
Fish ponds for pangas farming in rural Bangladesh

(P<0.05) of pond size in the different feeding practices. The highest average pond size was found in intensive farming (0.36 ha) followed by semi-intensive (0.21 ha) and traditional (0.12 ha). The average water depth of a pond in the rainy season and in the dry season were estimated at 1.64 m and 1.15 m, respectively. The principal water sources for ponds are rainfall, ground water (i.e. through tube-wells), and sometimes river water, via canals.

TABLE 10
Number of farmer's pond, average size and water depth by category of respondents

No. of pond, size and water depth	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
1 pond	13	65	19	95	20	100	52	86.7
2 ponds	7	35	1	5	0	0	8	13.3
Total	20	100	20	100	20	100	60	100
Average pond size (ha)	0.36		0.21		0.12		0.23	
Water depth, rainy season (m)	1.83		1.54		1.65		1.64	
Water depth, dry season (m)	1.24		1.03		1.19		1.15	

Most of the ponds are owned by the farmers themselves. Seventy percent of the respondents reported single ownership of ponds, while 20 percent were co-owners under a multiple ownership arrangement, and ten percent had user rights under lease arrangements. Annual leasing rates averaged US$138.5 per ha, ranging from US$92.3 to 230.8 per ha, for periods of 12 to 24 months. Lease value varied from one site to another depending on the locality, soil fertility, topography of the soil and distance from the road. Table 11 shows that the highest percentage of single lease ponds were noted among intensive farms (20 percent) compared with semi-intensive (10 percent) and traditional (0 percent). On the other hand, the highest percentage of single ownership ponds were reported in traditional farming (80 percent) followed by semi-intensive (75 percent) and intensive farming (55 percent). Seventy five percent of ponds had two owners and 25 percent had three owners.

TABLE 11
Ownership of ponds by farmers in different farming systems/feeding practices

Pond ownership	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Single ownership	11	55	15	75	16	80	42	70
Multiple ownership	5	25	3	15	4	20	12	20
Single lease	4	20	2	10	0	0	6	10
Total	**20**	**100**	**20**	**100**	**20**	**100**	**60**	**100**

The survey reveals that 38.3 percent of ponds were used only for fish culture and the remainders (61.7 percent) were used for multipurpose (Table 12) activities such as washing clothes and dishes, bathing water, homestead gardening, livestock watering and irrigating crops. The highest number of farmers using ponds only for fish culture was observed among intensive farmers (70 percent) compared with semi-intensive (40 percent) and traditional (5 percent). In general, fish farming does not interfere with the multipurpose use of ponds, providing strong incentives for pond owners to safeguard the quality of pond water.

TABLE 12
Pond utilization by farmers in different farming systems/feeding practices

Pond utilization	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Fish culture only	14	70	8	40	1	5	23	38.3
Multipurpose	6	30	12	60	19	95	37	61.7
Total	**20**	**100**	**20**	**100**	**20**	**100**	**60**	**100**

3.3.2 Farm production

All interviewed farmers practised pangas monoculture. The peak season for pangas farming is from March to February. The majority of fish farmers stocked their ponds from as early as March to May and harvested their fish after three months, and subsequently at regular intervals until the end of the year. The culture period is from 9 to 12 months. Table 13 shows that around 40 percent cultured for 10 months, 38.3 percent of farmers for 11 months and the remainder cultured for nine (6.7 percent) and 12 (11.7 percent) months. The culture period of ponds in the study area is shorter than elsewhere in the country because of the 2–3 month cold and dry season (November–February) when the water temperature drops to less than 15°C. Lower temperatures reduce the pangas growth rates.

TABLE 13
Average culture period of pangas by different farming systems/feeding practices

Culture period	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
9 months	0	0	2	10	2	10	4	6.7
10 months	3	15	10	50	13	65	26	43.3
11 months	10	50	8	40	5	25	23	38.3
12 months	7	35	0	0	0	0	7	11.7
Total	**20**	**100**	**20**	**100**	**20**	**100**	**60**	**100**

3.3.3 Stocking strategies and rates

Farmers stock ponds with fingerlings distributed by itinerant seed traders. Pangas culture in ponds was fully dependent on hatchery produced fingerling. The most common stocking frequency in traditional farms was once per year (95 percent of respondents), with a small minority (5 percent of respondents) stocking twice. All intensive farmers, and 90 percent semi-intensive, reported multiple stocking, respectively (Table 14). About 15 percent, 80 percent and 5 percent of intensive farmers were observed to practise annual stocking frequencies of twice, three times and four times, respectively.

TABLE 14
Stocking frequency (no. per year) by different farming systems/feeding practices

Stocking frequency	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Single	**0**	**0**	**2**	**10**	**19**	**95**	**21**	**35.0**
Twice	3	15	15	75	1	5	19	31.7
3 times	16	80	3	15	0	0	19	31.7
4 times	1	5	0	0	0	0	1	1.7
Total	**20**	**100**	**20**	**100**	**20**	**100**	**60**	**100**

The average annual stocking density of fingerlings was estimated at 23 847 per ha, varying from 12 065 in traditional systems to 23 575 in semi-intensive and 35 900 in intensive systems (Table 15). There was a significant difference ($P<0.05$) in stocking densities in different culture systems. The average size of fingerlings stocked at 6.0 cm in length and 11.6 g in weight. There was little difference between average sizes of fingerlings stocked by farming system.

3.3.4 Fertilization

All intensive and semi-intensive farmers used fertilizers for grow out (Table 16). However, only 35 percent of traditional farmers used fertilizer, mainly cow dung which is relatively cheap and abundant in the study area while the rest (65 percent), did not use fertilizer due to lack of money and poor knowledge on fish farming. The use of fertilizers has influenced the increase in the growth of pangas. The purpose of using fertilizers in the pond is to create conditions which help to increase the growth of good quality natural food (e.g. phytoplankton and zooplankton) thereby increasing fish production.

TABLE 15
Mean stocking rate, size and weight of fingerlings by different farming systems/feeding practices

Fingerlings	Intensive	Semi-intensive	Traditional	All categories
Stocking rate (No./ha/year)	35 900	23 575	12 065	23 847
Size (cm)	6.0	6.0	5.9	6.0
Weight (g)	12.5	11.5	10.7	11.6

TABLE 16
Use of fertilizers by farmers in different farming systems/feeding practices

Use of fertilizers	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Yes	20	100	20	100	7	35	47	78.3
No	0	0	0	0	13	65	13	21.7
Total	**20**	**100**	**20**	**100**	**20**	**100**	**60**	**100**

Fish farmers use two types of fertilizer namely: organic (mainly cow dung) and inorganic [urea and triple super phosphate (TSP)]. The most widely used fertilizers were cow dung (60 percent), urea (57 percent) and TSP (43 percent) at varying frequencies and rates. On average, annual fertilization rates were pegged at 903 kg/ha of cow dung, 259 kg/ha of urea and 192 kg/ha of TSP (Table 17). Cow dung is relatively cheaper and easily accessible in the study area.

Intensive farmers used more fertilizers than the other two groups. Table 17 also shows that the average annual fertilization rates were 970 kg/ha of cow dung, 288 kg/ha of urea and 180 kg/ha of TSP. In case of semi-intensive farming, the average annual fertilization rates were 811 kg/ha of cow dung, 218 kg/ha of urea and 233 kg/ha of TSP. It is interesting to note that only cow dung was used in traditional farming with an average annual fertilization rate of 650 kg/ha.

3.3.5 Feeds and feeding rates

Supplementary feeds were used by all of the traditional farmers for pangas farming. In general, farmers were using a mixture of rice bran, wheat bran and oil cake (Figure 3). Among traditional farmers, ten percent of respondents applied feed once daily while 25 percent applied twice a week and 65 percent at irregular intervals (Table 18). On the average, annual feeding rates per ha were estimated at 2 054 kg of rice bran, 2 071 kg of wheat bran and 1 665 kg of oil cake; for an aggregate annual feeding rate per ha of 5 790 kg. As this type of feed is slow sinking, almost all farmers resorted to the broadcast method of feeding. The average composition of supplementary feed is as follows: 15 percent moisture, 18 percent protein, 10 percent lipid, 21 percent ash, 18 percent fiber and 18 percent nitrogen free extract (NFE) (Table 19).

FIGURE 3
Application of supplementary feed by broadcasting

TABLE 17
Frequency and rate of fertilization by different farming systems/feeding practices

Frequency and rate of fertilization	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Cow dung								
Never	0	0	11	55	13	65	24	40.0
Daily	0	0	0	0	0	0	0	0
Weekly	0	0	0	0	0	0	0	0
Bi-weekly	9	45	0	0	0	0	9	15.0
Monthly	11	55	9	45	0	0	20	33.3
Irregular	0	0	0	0	7	35	7	11.7
Total	**20**	**100**	**20**	**100**	**20**	**100**	**60**	**100**
Rate (kg/ha/year)	**970**		**811**		**650**		**903**	
Urea								
Never	0	0	6	30	20	100	26	43.3
Daily	0	0	0	0	0	0	0	0
Weekly	0	0	0	0	0	0	0	0
Bi-weekly	17	85	4	20	0	0	21	35.0
Monthly	3	15	10	50	0	0	13	21.7
Irregular	0	0	0	0	0	0	0	0
Total	**20**	**100**	**20**	**100**	**20**	**100**	**60**	**100**
Rate (kg/ha/year)	**288**		**218**		**0**		**259**	
TSP								
Never	0	0	14	70	20	100	34	56.7
Daily	0	0	0	0	0	0	0	0
Weekly	0	0	0	0	0	0	0	0
Bi-weekly	9	45	2	10	0	0	11	18.3
Monthly	11	55	4	20	0	0	15	25.0
Irregular	0	0	0	0	0	0	0	0
Total	**20**	**100**	**20**	**100**	**20**	**100**	**60**	**100**
Rate (kg/ha/year)	**180**		**233**		**0**		**192**	

TABLE 18
Feeding frequency and rate by different farming systems/feeding practices

Feeding frequency and rate	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
More than once daily	20	100	1	5	0	0	21	35.0
Once daily	0	0	19	95	2	10	21	35.0
Twice/week	0	0	0	0	5	25	5	8.3
Irregular	0	0	0	0	13	65	13	21.7
Total	**20**	**100**	**20**	**100**	**20**	**100**	**60**	**100**
Rate (kg/ha/year)	**22 370**		**13 010**		**5 790**		**13 723**	

In semi-intensive farms, feeds were used to supplement the natural food produced in the pond through fertilization. All respondents in semi-intensive farming were using home/farm-made aquafeed for pangas farming (Figure 4). The feed ingredients that were mainly used included; rice bran, wheat bran, oil cake, fishmeal, flour, dried fish, oyster shell, salt and vitamins. This feed was prepared by a machine mixing of 30 percent rice bran and wheat bran, 30 percent mustard oil cake, 15 percent fishmeal, and 25 percent others. The average proximate composition of farm-made aquafeed is: 14 percent moisture, 22 percent protein, 12 percent lipid, 19 percent ash, 12 percent fiber and 18 percent NFE (Table 19). According to the survey of 20 respondents, 95 percent of farmers applied feed once daily while only five percent applied more than once daily (Table 18). On average, annual feeding rate was 13 010 kg/ha.

Pangas growth in intensive farming is primarily dependent upon an adequate supply of commercial fish feeds (Figure 5), both in terms of quality and quantity. There are about 25 commercial fish feed producers in Bangladesh (Kader, 2003). There was a significant difference ($P<0.05$) of feeding rates by culture systems. The average annual feeding rate in intensive farming was 22 370 kg/ha. All farmers applied feed more than once daily. As these types of feed are of slow sinking, feeds were applied by broadcasting (Figure 6). The composition of commercial feed is: 11 percent moisture, 30 percent protein, 15 percent lipid, 15 percent ash, 8 percent fibre and 21 percent NFE. The protein and lipid levels of industrially manufactured pelleted feeds are higher than farm-made aquafeed and supplementary feed (Table 19).

TABLE 19
Average proximate composition (percent of dry matter basis) of different feeds used for pangas farming

Nutrients	Industrially manufactured pelleted feed*	Farm made aquafeed**	Supplementary feed**
Moisture	11	14	15
Crude protein	30	22	18
Crude lipid	15	12	10
Ash	15	19	21
Crude fiber	8	12	18
Nitrogen free extract	21	18	18

*Values of the industrially manufactured pelleted feed are recorded from feed bag; ** Values of farm- made aquafeed and supplementary feed are from Kader (2003).

3.3.6 Fish yield

According to the survey, the average annual yield of pangas was estimated at 8 343 kg/ha in 2005. Table 20 shows that the highest average annual pangas production per ha pond was observed in intensive farming (13 945 kg) followed by semi-intensive (7 705 kg) and traditional (3 380 kg) farming. There was a significant difference ($P<0.05$) of fish yields in different farming systems, because of the differences of farm size, feed and seed inputs and management skill. Yields were a function of stocking density used in different farming systems. A lower FCR (feed conversion ratio) obtained in intensive farming was primarily a result of fertilization. Intensive farmers also produced more fish due to a combination of higher input of feed and seed, larger pond size and higher investment. However, the FCR was lower in intensive practice due to use of quality pelleted feed. Fertilizers whilst not common in pangas farming, were used to maintain water quality to enhance the flavor of pangas to counteract the bad flavor due to high stocking and the high feeding rate.

A number of interdependent factors affected growth rates and production. These included stocking rate, the quality and quantity of feed supply, water quality, and other aspects of pond management. The size of fish at stocking, the duration of culture[8], mortality and the size at which the fish are harvested also influence total yield. The current production level suggests that the average production of pangas has increased in the study area over recent years. The production of pangas of the surveyed farms was significantly higher than carp farming in other parts of the Mymensingh area. Pangas farming allows for very high densities resulting in much higher production as compared with carp. The annual yields of carps in the Greater Mymensingh area averaged 3 300 kg/ha (Winrock International, 2004) or 3 100 kg/ha (ADB, 2005), as compared with 8 343 kg/ha in pangas.

FIGURE 4
Mixed ingredients for preparation of farm-made aquafeed

[8] Intensive farming required multiple stocking and multiple harvesting with short culture periods. Traditional farming uses single stocking with a longer culture duration.

FIGURE 5
A farmer carrying industrially-manufactured pelleted feeds

Responses concerning the reasons for increased pangas production included an increased supply/availability of feed and quality fry, reduced mortality of fish, and better management. According to the survey of 60 farmers, 33 (55 percent) respondents believed that they could produce more fish mainly by applying more feeds (73 percent), high stocking of fry (18 percent) and better management (9 percent). The reasons given by the 45 percent of respondents who thought that they could not produce more fish were lack of money for inputs as well as high production costs (78 percent), limited knowledge (18 percent) and poor market facility (4 percent).

TABLE 20
Productivity of pangas and FCR by different farming systems/feeding practices

Factors/items	Intensive	Semi-intensive	Traditional	All categories
Stocking rate (No./ha/year)	35 900	23 575	12 065	23 847
Yield (kg/ha/year)	13 945	7 705	3 380	8 343
Amount of feed used (kg/ha/year)	22 370	13 010	5 790	13 723
FCR	1.60	1.69	1.71	1.64

The FCR[9] was computed for pangas farming. FCR is calculated from the kg of feed that are used to produce one kg of fish. A low FCR normally illustrates good management practice, with no overfeeding. Overfeeding or underfeeding will increase the FCR. Regardless of feeding practices, the average FCR was calculated at 1.64 in the study area. The highest average FCR was estimated in traditional farming at 1.71 compared with semi-intensive and intensive farming at 1.69 and 1.60, respectively (Table 20).

FIGURE 6
Application of industrially-manufactured pelleted feed by hand

Most of the harvested pangas (Figure 7) do not reach consumers directly from producers. A large number of rural poor are involved in the domestic fish marketing chain as local agents, traders, intermediaries, day labourers and transporters. The market chain from farmers to consumers encompasses mainly primary, secondary and retail markets, involving sales agents, suppliers, wholesalers and retailers. In general, trucks and pickups are used to transport live pangas to the markets. Plastic containers are commonly used for keeping the pangas during transport. Pangas are traded whole, un-gutted, and fresh without processing apart from sorting and icing. The price of pangas depends on supply and demand (in particular seasonality), quality, size and weight. The average farm-gate price of pangas was found at US$0.615 per kg.

[9] Biological FCR is the net amount of feed used to produce one kg of fish, while the economic FCR takes into account all the feed used, meaning that the effects of feed losses and mortalities, for example, are included (Aquamedia, 2006).

3.4 Comparative analysis of production costs

Data on pangas farming production costs were collected to assess their differences between farming categories. The following elements were assessed in the cost analysis:

1. costs: including variable costs, such as seed, feed, fertilizers, labour and opportunity costs, harvesting and marketing costs, and miscellaneous, which vary with outputs; and fixed and indirect operating costs, such as staff salary, interest, land use cost and depreciation, which are usually independent of the level of production;
2. assessment of key factors affecting pangas production.

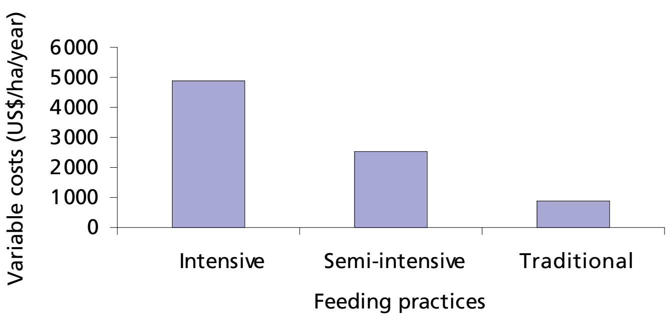
Particular attention was directed to addressing such questions as:

- Which inputs are significant in explaining variation in output from various farming categories?
- Are there economies of scale in pangas production?
- Are farmers making optimal use of inputs?
- Are they technically and economically efficient?
- What constraints inhibit increased production and profitability of existing pangas farming?

FIGURE 7
Harvesting of fish

It is essential to farm development and management to know the production costs and their performance, identifying the main items where cost efficiencies can be achieved. Production cost data also helps the farmers in decision making and in adjusting to changes, and determines the sales level under which the product cannot be sold without incurring a loss.

FIGURE 8
Variable costs for pangas farming by different feeding practices



3.4.1 Variable costs

The average annual variable costs for pangas farming was estimated at US$2 751 per ha for all feeding practices. There was a significant difference ($P<0.05$) of annual variable costs per ha farm in the different feeding practices, varying from US$4 856 in intensive farming, to US$2 506 in semi-intensive and US$892 in traditional farming (Figure 8). Variable costs in pangas culture are as follows:

3.4.2 Labour costs

Labour was one of the most important inputs in the production process of pangas farming. The sources of supply of human labour were: i) family labour,[10] for which no payment was made; and ii) hired labour, for which farmers had to pay in cash.

[10] Exact quantification of family labour was a challenging task, because the farmers often could not estimate distinctly the use of family labour for different purposes. To overcome these problems, the period of time spent by the family members in different operations was carefully assessed.

Sometimes provision of incentives in the form of food and tobacco were provided to the hired labour and the value of these items was also added to determine the actual cash amount paid for the labour. The hired labour can be further classified into: i) casual hired labour and ii) annually hired labour.

To determine the cost of unpaid family labour the opportunity cost[11] principle was adopted. In this study, a man-day was considered to be 8 hours of work. The labour of women and children has been converted into man equivalent days by representing a ratio of 2 children days = 1.5 women days = 1 man day (Miah, 1987). Labour wage range varies with respect to nature of work, location, number of workers required, and season. The peak labour demand, between February to April, coincides with rice weeding and later harvesting. However, during the early monsoon months of June to August when little work is available, the normal wage rate drops to US$0.92 to 1.30 per day. The average wage rate for pangas farming was estimated at US$1.23/day, ranging from US$0.92 to 1.85/day.

From pond preparation to harvesting and marketing of pangas, human labour was required in different operations and management. The average annual human labour cost was calculated at US$241 per ha farm. Labour utilization and the relevant cost are shown in Table 21 for the different farming systems. The highest average labour cost was noted in intensive farming (US$360/ha/year) followed by semi-intensive (US$240.3/ha/year) and traditional (US$124/ha/year) farming.

TABLE 21
Average annual quantity and cost of human labour by farming systems/feeding practices

Labour	Intensive	Semi-intensive	Traditional	All categories
Man days	293.0	195	101.0	196.0
Wage (US$/day)	1.23	1.23	1.23	1.23
Cost (US$/ha/year)	**360.0**	**240.3**	**124.0**	**241.4**

Note: Includes family labour. Wages represent an average of different payments for different tasks

3.4.3 Cost of fertilizers

Pangas farmers use two types of fertilizer: organic (mainly cow dung); and inorganic (urea and TSP). The price of fertilizers was calculated based on the prevailing market price. The prices of these fertilizers were assumed to be same in all categories of farms. The average prices per kg of these fertilizers were US$0.0077 for cow dung (i.e. US$7.7 per 1000 kg), US$0.092 for urea and US$0.21 for TSP. The average annual costs of inorganic and organic fertilizers were calculated at US$53.5 and US$3.9 per ha, respectively (Table 22). The highest average annual cost of fertilizers was noted among intensive farms at US$112.3 per ha, compared with semi-intensive (US$54.3 per ha) and traditional (US$5.6 per ha) farming.

TABLE 22
Mean average cost of fertilizers (US$/ha/year) by different farming systems/feeding practices

Fertilizers	Intensive	Semi-intensive	Traditional	All categories
Inorganic	103.8	51.5	5.1	53.5
Organic	8.5	2.8	0.5	3.9
Total	**112.3**	**54.3**	**5.6**	**57.4**

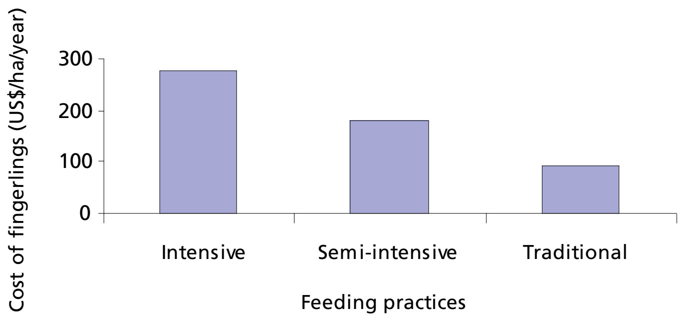
[11] Opportunity costs refer to the costs associated with giving up an opportunity. The opportunity cost creates an implicit price relationship between competing alternatives. The opportunity cost of a human labour is its value in its best alternative use. According to Hulse *et al.* (1982), opportunity cost is the return given up by not participating in the next best alternative activity.

3.4.4 Cost of fingerlings

Stocking of fingerlings is one of the major input costs in pangas farming. Farmers normally purchased fingerlings from the fry collectors and/or hatcheries. There was a variation of fingerling prices linked to the source and the time of purchase. The cost was calculated based on the actual prices paid. The average price of pangas seed was US$7.7 per 1000 fingerlings. Regardless of farm categories, the average annual cost of fingerlings was calculated at US$183.4 per ha. The highest average annual cost of fingerlings was found in intensive farming (US$276.2 per ha) followed by semi-intensive (US$181.3 per ha) and traditional (US$92.8 per ha) farming (Figure 9). There was a significant difference (P<0.05) of cost of fingerlings in different farming categories because higher stocking densities were used in intensive and semi-intensive farming.

FIGURE 9

Cost of fingerlings by different farming systems/feeding practices



3.4.5 Cost of feeds

Feed is one of the most essential inputs for increasing fish production. Feed cost constitutes the highest single cost item in intensive, semi-intensive and traditional grow-out farming operations. Farmers used industrially manufactured pelleted feed, farm-made aquafeed and supplementary diet (rice bran, wheat bran and oil cake) in intensive, semi-intensive and traditional feeding practices, respectively. The average cost of these feeds were US$0.18, US$0.14 and US$0.09 per kg for industrially manufactured pelleted feed, farm-made aquafeed and supplementary feed, respectively. The total amount of feeds per ha per year varied by different culture strategies. Regardless of farm categories, the average annual cost of feed was calculated at US$2 128 per ha. There was a significant difference (P<0.05) of feed cost in different feeding practices, an average of US$3 957, US$1 853 and US$574 per ha per year were estimated in intensive, semi-intensive and traditional farming systems, respectively (Figure 10). Results showed that intensive farms incurred the highest feed cost among all farm categories.

3.4.6 Other variable costs

The costs of harvesting, marketing, electricity, vitamin premix, and medicine were calculated under the heading of other variable costs. The average other variable costs were estimated at US$167 per ha per year, varying from US$227 in intensive feeding to US$178 in semi-intensive and US$96 in traditional feeding (Figure 11). There was a significant difference (P<0.05) of other variable costs in the different feeding practices.

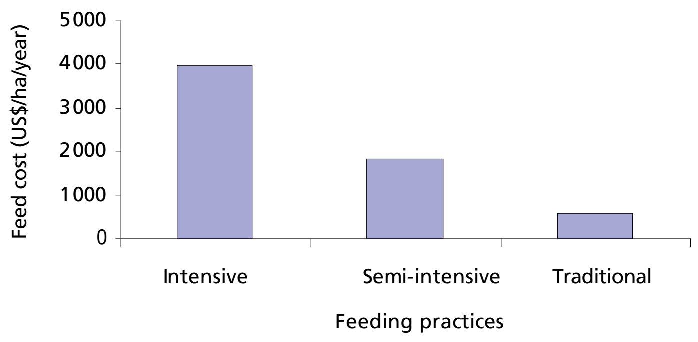
3.4.7 Other costs

Pangas farming required some fixed costs such as depreciation[12] (i.e. water pump, nets and feed machines), permanent staff salary including caretaker and guard,[13] land

[12] [(purchase price – salvage value) / economic life]

[13] Most of the intensive and semi-intensive farmers tend to recruit night guard to protect against poaching which is a common problem in the study area.

FIGURE 10
Cost of feeds by different feeding practices



use cost (or lease money) and interest on operating capital.

Interest on operating capital was calculated by taking into account the amount spent in cash for pangas farming. The amount of money needed to meet the expanse of inputs such as fingerlings, feed, fertilizers, labour are treated as operating capital in this study. Interest on operating capital was charged at the rate of 15 percent per annum and was estimated for the period during the culture period. The standard formula for calculation of interest on operating capital is as follows:

Interest on operating capital (OC) = Alit (Miah, 1987)

Where,

Al = Total investment/2

i = Interest rate which was 15 percent per year during the study period

t = Time (length of the period of pangas cultivation)

The cost of land use may be anticipated by using one of the following three alternative concepts:

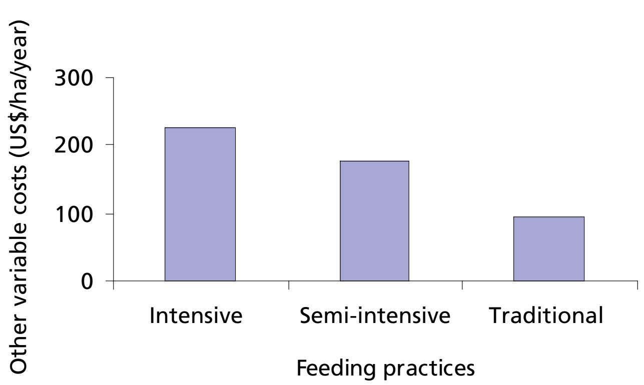
i) interest on the value of land (generally five percent);

ii) valuation of land at its rental price (or if it is leased out); and

iii) foregoing incomes from alternative use.

The average annual fixed costs for pangas farming was estimated at US$187 per ha. There was a significant difference (P<0.05) in fixed costs in the different feeding practices, varying from US$285 per ha per year in intensive to US$188 in semi-intensive and US$89 in traditional farming (Table 23). Among the fixed costs, the average annual depreciation cost, salaries, interest and land use cost were calculated at US$27, US$26, US$67 and US$65 per ha respectively. Figure 12 shows the highest average annual fixed costs such as depreciation, staff salary, interest and land use cost reported by intensive, semi-intensive and traditional farms respectively.

FIGURE 11
Other variable costs for pangas farming by different feeding practices

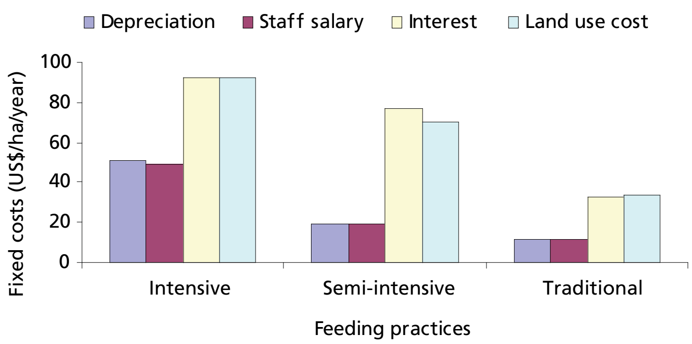


3.4.8 Total production costs

Table 23 shows that total costs of pangas farming for all sampled farmers averaging US$2 964 per ha per year, varying from US$5 217 in intensive farming to US$2 694 in semi-intensive and US$981 in traditional farming. Regardless of farm category, average variable costs and fixed costs were estimated at US$2 777 and US$187 per ha per year, respectively. Variable costs accounted for 94 percent of total costs, varying from 95 percent in intensive to 93 percent in semi-intensive and

91 percent in traditional farming. The cost of feeds dominated all other costs representing about 72 percent of total costs (77 percent of variable costs) varying from 76 percent in intensive to 69 percent in semi-intensive and 59 percent in traditional systems (Figure 13). The cost of fertilizers accounted for 2 percent of total costs, varying from 2.2 percent in intensive to 2 percent in semi-intensive and 0.5 percent in traditional farming. The relative proportion of the costs of labour, fingerlings, and other variable costs averaged 8 percent, 6 percent and 5.5 percent of total costs, respectively. Fixed costs represented 6 percent of total costs, varying from 5.4 percent in intensive to 7 percent in semi-intensive and 9 percent in traditional farming.

FIGURE 12
Fixed costs for pangas farming by different feeding practices



All interviewed farmers stated that production costs had increased in recent years. In response to the question on how the costs of pangas farming could be reduced, key factors that were cited included:

- the use of farm-made, cheap and locally produced compound feed;
- less inputs (feed, seed and fertilizers); and
- better management.

TABLE 23
Mean average total production costs (US$/ha/year) for pangas farming by different farming systems/feeding practices. Values in parentheses indicate the percent of total costs

Cost items	Intensive	Semi-intensive	Traditional	All categories
i) Variable costs (VC)				
1. Labour (family & hire)	360 .0 (6.9%)	240.3 (8.9%)	124.0 (12.6%)	241.4 (8.1%)
2. Fertilizers	112.3 (2.2%)	54.3 (2.0%)	5.6 (0.5%)	57.4 (1.9%)
3. Fingerlings	276.2 (5.3%)	181.3 (6.7%)	92.8 (9.5%)	183.4 (6.2%)
4. Feeds	3 956.6 (75.8%)	1 852.6 (68.8%)	573.7 (58.5%)	2 127.7 (71.8%)
5. Other variable costs	227.4 (4.3%)	177.7 (6.5%)	96.1 (9.7%)	167.1 (5.6%)
Subtotal	**4 932.5 (94.5%)**	**2 506.2 (93.0%)**	**892.2 (91.0%)**	**2 777.0 (93.7%)**
ii) Fixed costs (FC)				
1. Depreciation	50.8 (1.0%)	19.6 (0.7%)	11.1 (1.1%)	27.2 (0.9%)
2. Salary of permanent staff	49.2 (0.9%)	19.6 (0.7%)	11.1 (1.1%)	26.7 (0.9%)
3. Interest	92.7 (1.8%)	76.9 (2.9%)	32.3 (3.3%)	67.3 (2.3%)
4. Land use cost	91.9 (1.8%)	70.0 (2.6%)	33.8 (3.4%)	65.3 (2.2%)
Subtotal	284.6 (5.4%)	187.7 (6.9%)	88.5 (9.0%)	186.5 (6.3%)
iii) Total costs (TC=VC+FC)	**5 217.1 (100%)**	**2 693.9 (100%)**	**980.7 (100%)**	**2 963.5 (100%)**

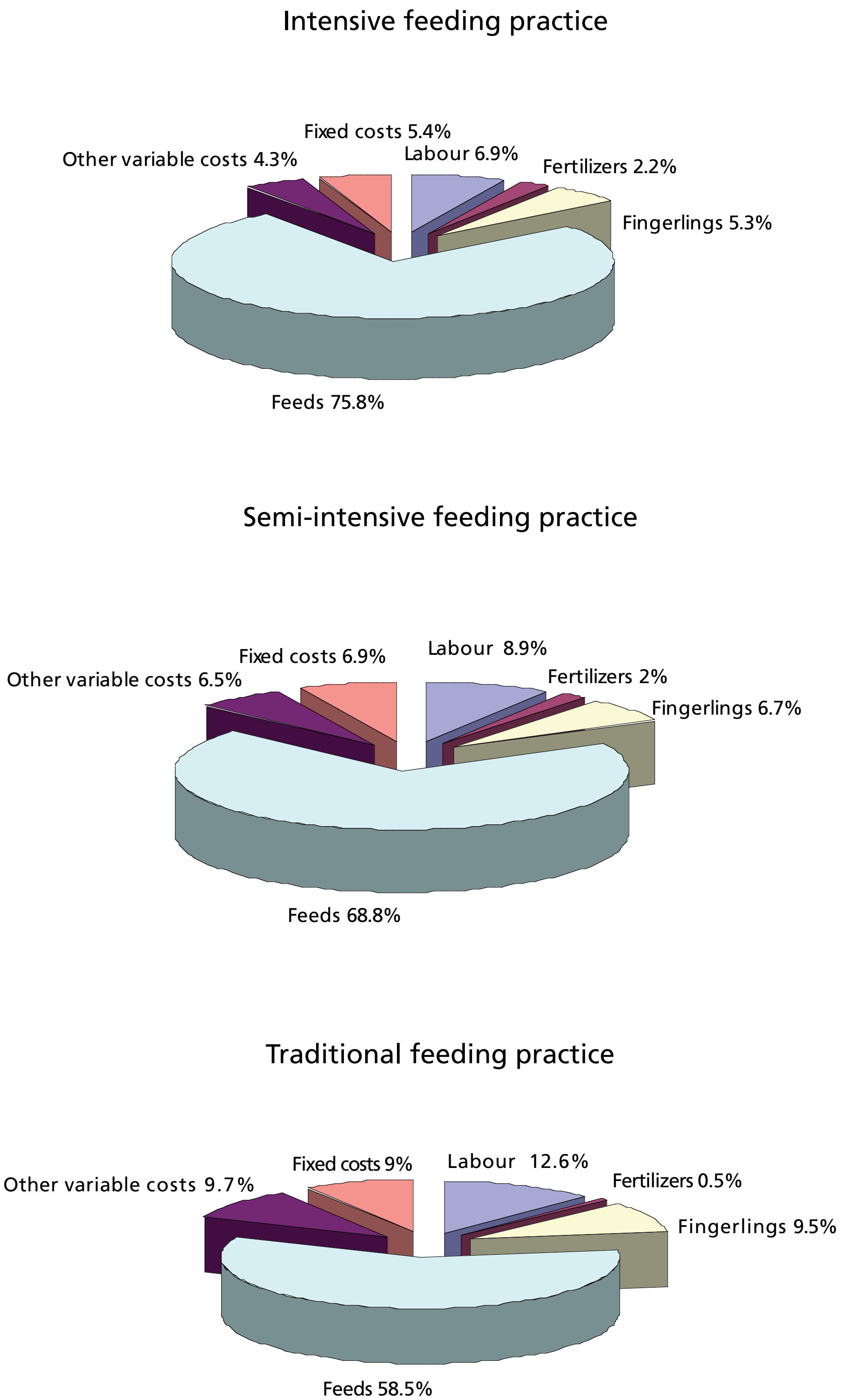
3.5 Comparative analysis of farm income and economic indicators

3.5.1 Gross revenue

Gross revenue is the pecuniary value of total production (gross revenue = sum of value of outputs). Gross revenue was calculated by multiplying the total amount (sold and consumed) of production (kg) by their respective market prices (US$/kg). The average market price[14] of pangas was found at US$0.615 per kg. Gross revenue was calculated

[14] There was no difference in pangas price in different farming systems. In general, traditional farmers produced larger pangus due to single stocking (i.e. longer culture period) while intensive and semi-intensive farmers produced smaller pangas due to multiple stocking and multiple harvesting (i.e. short culture period).

FIGURE 13
Percent of total production costs in different farming systems/feeding practices



at US$5 134 per ha per year, varying from US$8 582 in intensive farming to US$4 742 in semi-intensive and US$2 080 in traditional farming (Table 24). The highest average gross revenue was reported by intensive farmers due to higher production, whilst the lowest average gross revenue was found for traditional farmers due to lower production. The average annual gross revenue per ha is significantly higher among intensive farmers compared with semi-intensive and traditional farmers.

TABLE 24
Mean average gross revenue of pangas production by different farming systems/feeding practices

Pangas farming	Intensive	Semi-intensive	Traditional	All categories
Production (kg/ha/year)	13 945	7 705	3 380	8 343
Market price (US$/kg)	0.615	0.615	0.615	0.615
Gross revenue (US$/ha/year)	8 581.5	4 741.5	2 080	5 134.3

3.5.2 Gross aquaculture margin
Once the fixed investments are made, the aquaculture farmers' decisions should be based on the expected returns or income above variable costs. Fixed investments are considered as sunk costs and may not be recovered for at least one farming season. The highest annual average income above variable cost per ha was revealed by intensive farms (US$3 649) compared with semi-intensive (US$2 235) and traditional (US$1 189) farms (Table 25). It is calculated that all farms were able to generate positive returns to variable costs. These findings indicate that all farming systems, including traditional farms are willing to pursue pangas farming as the returns above variable costs are positive.

3.5.3 Net margin/return
Net return is defined as gross revenue minus total production costs. Regardless of farming categories, the annual net return per ha of pond averaged US$2 170. Despite a higher average production cost per ha, the average annual net return was higher in intensive farming system at US$3 364 compared with US$2 048 in semi-intensive and US$1 099 in traditional farming (Table 25). Despite a lower production cost among traditional farmers, their low production has resulted in lower net returns. On the other hand, intensive farmers' higher production costs are offset by higher yield resulting in a higher net return. Almost all interviewed farmers stated that their returns had decreased as costs of pangas farming had increased significantly while the price of pangas has not increased to a similar degree. However, most of the farmers have improved their social and economic status as a result of pangas farming. In addition pangas farming has generated employment opportunities. Such improved conditions may be described on the basis of qualitative indicators. These comprise: increased food consumption; increased social status; and involvement of women in pangas farming. Study results suggest that farmers have broadly improved their standards of living, purchasing power, choice, and ability as an economic sector.

3.5.4 Returns to land and labour
The average net returns to land of intensive, semi-intensive and traditional farms were US$3 273, US$1 978 and US$1 066, respectively (Table 25). Similarly, the average net retur ns to labour among all feeding practices are positive. These findings indicate that all farming systems, including traditional farms are willing to pursue pangas farming as the returns to land and labour are positive.

3.5.5 Benefit-cost ratio
Benefit-cost ratio (BCR) is defined as gross revenue divided by total production costs, which implies that a ratio of 1.0 means that the operation is at break-even position. The benefit-cost ratios were estimated at 2.12, 1.76 and 1.64 for traditional, semi-intensive

and intensive farms, respectively (Table 25). The findings indicate that the traditional farms are able to recover US$2.12 per US$1.00 of investment while semi-intensive and intensive farms generate a return of US$1.76 and US$1.64, respectively.

TABLE 25
Financial and economic indicators of pangas production by feeding practices

Financial and economic indicators	Intensive	Semi-intensive	Traditional	All categories
A. Total cost[1] (US$/ha/year)	5 217.1	2 693.9	980.7	2 963.5
B. Variable cost[2] (US$/ha/year)	4 932.5	2 506.2	892.2	2 777.0
C. Fixed cost[3] (US$/ha/year)	284.6	187.7	88.5	186.9
D. Gross revenue[4] (US$/ha/year)	8 581.5	4 741.5	2 080	5 134.3
E. Gross margin[5] (US$/ha/year)	3 649	2 235.3	1 187.8	2 357.3
F. Net margin/returns[6] (US$/ha/year)	3 364.4	2 047.6	1 099.3	2 170.4
G. Net returns to land[7] (US$/ha/year)	3 272.5	1 977.6	1 065.5	2 105.1
H. Net returns to labour[8] (US$/ha/year)	3004.4	1 807.3	975.3	1 929
I. Gross total factor productivity/benefit-cost ratio[9]	1.64	1.76	2.12	1.73
J. Break-even price[10] (US$/kg)	0.37	0.35	0.29	0.35
K. Actual price (US$/kg)	0.615	0.615	0.615	0.615
L. Break-even production[11] (kg)	8 478	4 377	1 593	4 816
M. Actual production (kg)	13 945	7 705	3 380	8 343
N. Survival rate[12] (percent)	89.4	84.6	77.8	83.9

[1] Total costs = variable costs + fixed costs (A = B + C)
[2] Sum of costs of fingerlings, fertilizers, feeds, hired and family labour, harvesting and marketing costs, and other variable costs
[3] Sum of land use cost, interest, depreciation and permanent staff salary
[4] The total amount of production (kg) multiplied by their respective market prices
[5] Gross revenue less variable costs (E = D – B)
[6] Gross revenue less total costs (F = D – A)
[7] Net margin/returns less land rent payment
[8] Net margin/returns less cost of labour
[9] Gross revenue divided by total costs (I = D/A)
[10] Total costs divided by total production (J = A/total production)
[11] Total costs divided by average price (L = A/average price of fish: US$0.615 per kg)
[12] (Number of pieces during harvest/number of pieces during stocking) x 100

3.5.6 Break-even price
Break-even price was estimated as total costs (US$/ha/year) divided by production of pangas (kg/ha/year). Regardless of different feeding practices, the average break-even price (cost per kg of fish production) was estimated at US$0.35 per kg (Table 25). This is against the prevailing market price of pangas, US$0.615 per kg. The break even prices for intensive, semi intensive and traditional farms were US$0.37 per kg (-39 percent), US$0.35 per kg (-43 percent), and US$0.29 per kg (-53 percent), respectively. These figures imply that all farming systems can significantly absorb price changes and still achieve profitability.

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

production costs in relation to the prevailing market price of fish per kg (i.e. total production costs/market price of fish per kg).

As shown in Table 25, the break-even production per ha farm for pangas is estimated at 4 816 kg for all categories. Regardless of farm categories, the average annual yield of pangas was found at 8 343 kg/ha. The over-all current performance of pangas production exceeded their break-even production level by 73 percent. This result suggests that regardless of farm categories, current pangas production 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 production per ha farm levels of intensive, semi-intensive and traditional are calculated at 8 478 kg, 4 377 kg and 1 593 kg, respectively. The average annual pangas production per ha pond in intensive, semi-intensive and traditional farming was found at 13 945 kg, 7 705 kg and 3 380 kg, respectively. These results indicate that the current pangas production performances by intensive, semi-intensive and traditional farms exceeded their respective break-even production levels by 64 percent, 76 percent and 112 percent, respectively. The break-even analysis on production levels imply that all farming categories were able to produce productivity levels that have exceeded break-even production levels.

3.5.8 Net return per kilo of fish

The net return per fish kg is the difference between market price (i.e. US$0.615 per kg) and production costs (i.e. US$0.355 per kg) of per fish kg. It can also be calculated as net return (US$/ha/year) divided by the yield of pangas (kg/ha/year). Table 26 shows that the average net return per kg of pangas was estimated at US$0.26. The highest average net return per kg of pangas production was found in traditional farming (US$0.33/kg) followed by semi-intensive (US$0.27/kg) and intensive (US$0.24/kg) farming. Comparing the farming systems, traditional farmers produced at least cost, with a higher net return per kg fish. Conversely, intensive farmers produced at higher cost, therefore having a lower net return per kg fish.

TABLE 26
Average net return per kg of pangas production by different categories of respondents

Pangas farming	Intensive	Semi-intensive	Traditional	All categories
Net return (US$/ha/year)	3 364.4	2 047.6	1 099.3	2 170.4
Production (kg/ha/year)	13 945.0	7 705.0	3 380.0	8 343.0
Net return per kg (US$/kg)	0.24	0.27	0.33	0.26

3.7 Overview of cost structure and profitability

The findings of the study show that the different farming systems have different cost structures, depending on the availability and quality of inputs, mainly feed, seed, fertilizers, labour and other factors (pond size, water quality and management). The average annual production costs varying from US$5 217 per ha for intensive farms to US$2 694 per ha for semi-intensive and US$981 per ha for traditional farms, there being significant difference. The total production costs per ha pond in intensive farming was higher than other two categories, mainly due to both higher variable costs and fixed costs (Table 27). The relatively higher cost of feed for intensive farmers appears to be due to the use of industrially manufactured pelleted feed.

Comparing the three farming systems, production cost was the lowest for traditional farmers, therefore having a lower production. In contrast, intensive farmers produced at highest cost, therefore having a higher production. Regardless of farming systems, yield of pangas averaged 8 343 kg/ha/year, ranging from 13 945 kg in intensive to 7 705 kg in semi-intensive and 3 380 kg in traditional farming. For intensive farming, increased feed supply (22 370 kg/ha/year) resulted in increased per ha pangas production.

However, additional costs reduced profitability per kg of pangas. The highest average net return per kg of pangas was found in traditional systems (US$0.33/kg) followed by semi-intensive (US$0.27/kg) and intensive (US$0.24/kg) farming.

Farmers in all feeding (farming) practices made a profit from pangas farming. On the average, the net return and the benefit-cost ratio is significantly different among the farming categories (Table 27). The highest benefit-cost ratio is found in traditional farming at 2.12, compared with 1.76 in semi-intensive and 1.64 in intensive systems. On the other hand, the highest net return per hectare is found in the intensive farming category, mainly due to the highest production, as producers appear to be able to afford more inputs, such as feed, seed, fertilizers and labour. However, due to the risk levels (i.e. flood, poaching, diseases, and a lower pangas market price) and high production costs, the profitability of intensive farming may not be acceptable over the longer term. It is therefore suggested that semi-intensive systems may be acceptable and it may be necessary to increase profitability by reducing production costs and better management practice.

The further development of the sector depends on its profitability, and increase in yield was the major means of increasing profit in all systems. Factors such as feed, seed, fertilizers and pond management all influence yield and profitability. Reduction in major variable costs, increased production per unit of pond, associated with increased growth rate, good management and increased price per quantity of pangas by aiming at higher valued production may all increase profit.

TABLE 27
Summary of major findings by different farming systems

Pangas farming	Intensive	Semi-intensive	Traditional	All categories
Pond size (ha)	0.36	0.21	0.12	0.23
Stocking rate (No./ha/year)	35 900	23 575	12 065	23 847
Feeding rate (kg/ha/year)	22 370	13 010	5790	13 723
Production (kg/ha/year)	13 945	7 705	3 380	8 343
FCR	1.60	1.69	1.71	1.64
Variable costs (US$/ha/year)	4 932.5	2 506.2	892.2	2 777.01
Fixed costs (US$/ha/year)	284.6	187.7	88.5	185.5
Total costs (US$/ha/year)	5 217.1	2 693.9	980.7	2 963.5
Gross revenue (US$/ha/year)	8 581.5	4 741.5	2 080.0	5 134.3
Net return (US$/ha/year)	3 364.4	2 047.6	1 099.3	2 170.4
Net return per kg fish (US$)	0.24	0.27	0.33	0.26
Benefit-cost ratio	1.64	1.76	2.12	1.73

3.6 Production problems

A number of constraints were reported by pangas farmers, including dike overflow, water pollution, poor water quality, natural disasters (flood, drought), excessive rainfall, theft, poisoning, high production costs, lack of credit facilities, and inadequate marketing facilities. Poaching of pangas is also a common problem in the study area, and is one of the biggest problems for the poor farmers. A few rich farmers tend to recruit guards or night watchmen to protect against theft and poisoning.

Farmers were requested to state problems that they faced with feed. Eighty eight percent of farmers identified the high feed price as the principal problem. Seven percent and five percent of farmers identified procurement problems and lack of feed availability as additional problems. Table 28 shows that all traditional farmers identified the high price of feed as the major problem, hence resorting to the use of supplementary feed. Semi intensive (90 percent) and intensive (75 percent) farmers were also concerned about the high costs of feed, citing feed costs as the major constraint against the greater expansion of pangas farming in the study area.

TABLE 28
Feed related constraints by farmers by different feed types/feeding practices

Constraints of feed	Intensive: pelleted feed		Semi-intensive: farm-made aquafeed		Traditional: supplementary feed		All categories	
	No.	%	No.	%	No.	%	No.	%
High price	15	75	18	90	20	100	53	88.3
Procurement problems	3	15	1	5	0	0	4	6.7
Less availability in market	2	10	1	5	0	0	3	5.0
Total	**20**	**100**	**20**	**100**	**20**	**100**	**60**	**100**

Farmers were also faced with problem concerning fingerlings. About 73 percent of farmers identified high fingerlings prices as one of their problems, while a further 17 percent and 10 percent mentioned poor quality and poor availability, respectively (Table 29). In case of traditional farming, the high price of fingerlings was identified by 95 percent of the farmer-respondents compared with 75 percent among semi-intensive and 50 percent among the intensive farmer-respondents. On the other hand, a respective 30 percent, 15 percent and 5 percent of intensive, semi-intensive and traditional farmer-respondents also identified poor quality of fingerlings as a problem.

TABLE 29
Fingerlings related constraints faced by farmers by different feeding practices/farming systems

Constraints regarding fingerlings	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
High price	10	50	15	75	19	95	44	73.3
Poor quality	6	30	3	15	1	5	10	16.7
Less availability in market	4	20	2	10	0	0	6	10.0
Total	**20**	**100**	**20**	**100**	**20**	**100**	**60**	**100**

Partial harvesting was practised by all of the farmers in the study area. In general, traditional farmers undertake their own harvesting. Conversely, semi-intensive and intensive farmers hired local labourers for the task.

Fifty five percent of pangas farmers identified lower market prices (than other species, e.g. carp) as a problem (Table 30). Since production decisions (e.g. investment and profits) are made on the current market price of pangas, any downward fluctuation in the market will affect the profitability as well as viability of the pangas farming.

Other problems included high transport costs (25 percent of respondents), poor road (17 percent) and intermediary influence (3 percent).

TABLE 30
Marketing related constraints faced by farmers by different feeding practices/farming systems

Marketing constraints	Intensive		Semi-intensive		Traditional		All categories	
	No.	%	No.	%	No.	%	No.	%
Falling market price	10	50	11	55	12	60	33	55.0
High transport costs	4	20	5	25	6	30	15	25.0
Poor road and transport facilities	5	25	3	15	2	10	10	16.7
Intermediary influence	1	5	1	5	0	0	2	3.3
Total	**20**	**100**	**20**	**100**	**20**	**100**	**60**	**100**

3.8 Statistical analysis

3.8.1 Production function model

Two forms of production function model were initially estimated to determine the effect of variable inputs. These were: 1) Linear and 2) Cobb-Douglas (Table 31). The Cobb-Douglas production function which is linear in its logarithmic form has several advantages (Smith, 1982) such as: 1) the elasticities of production which measure the responsiveness of output to increase units of input are identical to the production coefficients (b_i). Consequently, a percentage change in output that is brought about by a given percentage change in input use can be easily determined. 2) The sum of the production coefficients (Σb_i) can be interpreted as a measure of economies of scale. If $\Sigma b_i>1$, for example, positive economies of scale exist, this implies that a double of the use of all inputs will result in more than a doubling of output. 3) Input and output data can readily be used, without aggregation to estimate the parameters of the model. 4) The Cobb-Douglas function has only one degree of freedom per explanatory variable.

TABLE 31
Two forms of the production function

1. Linear
$Y = a + b_1X_1 + b_2X_2 + b_3X_3$ .... $+ b_nX_n$

2. Cobb-Douglas (log-linear)
$Y = a\ X_1^{b1}\ X_2^{b2}\ X_3^{b3}$ .... X_n^{bn}
Or
$\text{Log } Y = \text{Log } a + b_1 \log X_{1i} + b_2 \log X_{2i} + b_3 \log X_{3i}$ .... $b_n \log X_{ni} + \text{Log } U_i$

Where,
Y = output, X_i = inputs, b_i = factor (input) productivities, a = constants, and
U_i = random error or disturbance term

The Cobb-Douglas production function was chosen on the basis of best fit and significant result on output. Five inputs or explanatory variables were hypothesized to explain pangas farming. It was hypothesized that using all five inputs will have effect on production as well as income of farm. Regression analysis (ordinary least square method) was used to determine the effect of these inputs. The Cobb-Douglas function model of the following form was used for the analysis:

$Y = a\ X_1^{b1}\ X_2^{b2}\ X_3^{b3}\ X_4^{b4}\ X_5^{b5}\ e^U$

Or in its logarithmic form as:

$\text{Log } Y = \log a + b_1 \log X_{1i} + b_2 \log X_{2i} + b_3 \log X_{3i} + b_4 \log X_{4i} + b_5 \log X_{5i} + \text{Log } U_i$

Where,

Y = Gross revenue (US$)

a = Constant parameter in the equation, mathematically interpreted as the intercept

X_1 = Farm size (ha)

X_2 = Stocking cost (US$)

X_3 = Feed cost (US$)

X_4 = Fertilizer cost (US$)

X_5 = Labour cost (US$)

U_i = Random error or disturbance term (residual or error term which may result from measurement and stochastic errors)

$i = 1, 2, 3$ .... n

The explanatory variables (X_i) or inputs are sometimes known as target variables because they are subject to influence by the producer or decision maker (Chong and Lizarondo, 1982). Of the five explanatory variables specified in the model, all are within the control of producers. The production coefficients (b_i) or exponents in the Cobb-Douglas form are the elasticities of production. The bi terms are actually transformation ratios of the various inputs used in pangas production at different amounts.

The management factor was not included in the model because specification and measurement of management factor is almost impossible in the present study, since the farm operator is both a labourer and manager. Other independent variables like water quality and soil condition which might have affected production of farm enterprises were excluded from the model on the basis of some preliminary estimation.

Initially the results of the estimation for different farming categories were not fitting because of the small sample size, the wide range of observed values and multicolinearity among the independent variables. Of first 10 variables were included but to make it more meaningful, 5 of the insignificant variables were omitted to allow the selection of the most relevant explanatory variables.

3.8.2 Interpretation of results

Before interpreting the results obtained from the estimated revenue function, it is necessary to examine the function for its ability to explain output variation. Two interrelated measures of 'goodness of fit' are known as the correlation coefficient (R), and coefficient of multiple determination (R^2). The maximum possible value for R^2 is 1.0, which implies that 100 percent of the output variation is explained by the estimated function. In applied research using cross-sectional data, one would not expect to find such a high value for R^2 (Smith, 1982). The F-test is usually used to test the overall significance of the independent variables chosen for inclusion in the model. The sign test can also be applied to determine if each of the production coefficients (b_i) has the expected positive or negative sign. Finally, t-tests are used to test the significance of the individual production coefficients.

Estimated values of the coefficients and related statistics of Cobb-Douglas revenue function are presented in Table 32. Regression results showed that the coefficient of multiple determination (R^2) for different farming systems varies from 0.926 to 0.995 which indicates that 92 to 99 percent of the total variation in revenue of pangas farms are explained by the five (5) independent variables included in the model. It also indicates that excluded variables for gross revenue accounted for only 1 to 8 percent of the variation for three different farming systems. F-values of all individual equations are highly significant implying that all the included explanatory variables are important for explaining the variation of intensive, semi-intensive and traditional systems. Therefore t-values of the individual coefficients should be expected to be significant. The selected revenue functions have sufficient degrees of freedom for testing statistical significance and are stable with respect to the sign of their regression coefficients. The levels of significance used were one percent, five percent and ten percent.

The relative contribution of specified factors affecting revenue of pangas farming can be seen from the estimates of regression equation for three different farming systems. In total, there are five input coefficients for the production of selected systems and of those all coefficients had proper (positive) sign in semi-intensive and traditional farming. However, three coefficients had improper (negative) sign in intensive farming. Of the five explanatory variables in the model, four regression coefficients in each farming system are statistically significant at different level (0.01 to 0.10), with the exception of labour costs.

Farm size is a key factor in determining the extent of care and management of pangas farming. Size of farm is an important factor influencing the use of inherent inputs of farm income. It contributed 0.681 percent, 0.391 percent, and 0.284 percent in intensive, semi-intensive and traditional farming system, respectively. Farm size was the only factor that had proper sign of coefficient for each farming system. Therefore it is an important factor to increase or decrease the output.

The estimated coefficient of stocking cost was negative in the intensive systems (-0.081) at 5 percent level of significance. It implies that 1 percent increase in the cost of fingerlings, keeping other factors constant, would decrease gross revenue by 0.081 percent. However, the estimated coefficients of stocking cost were positive in semi-intensive (0.382) and traditional (0.557) farming systems and significant at the 1 percent and 5 percent level, respectively. It implies that 1 percent increase in the number of fingerlings stocked, keeping other factors constant, would raise the quantity of fish harvested by 0.382 percent and 0.557 percent in semi-intensive and traditional farming systems, respectively.

TABLE 32
Estimated values of coefficients and related statistics of Cobb-Douglas production function model

Explanatory variables	Intensive	Semi-intensive	Traditional
Y-intercept	2.37*** (0.55)	3.125*** (0.64)	2.580*** (0.578)
Farm size (X_1)	0.681** (0.062)	0.391*** (0.089)	0.284* (0.106)
Stocking cost (X_2)	-0.081** (0.034)	0.382*** (0.085)	0.557** (0.127)
Feed cost (X_3)	-0.191*** (0.045)	0.231*** (0.071)	0.365** (0.094)
Fertilizer cost (X_4)	-0.169* (0.071)	0.115** (0.092)	0.434** (0.125)
Labour cost (X_5)	0.580[ns] (0.172)	0.092[ns] (0.012)	0.041[ns] (0.011)
R	0.997	0.998	0.996
R^2	0.995	0.926	0.993
F value	1 696.06**	1 934.80**	1 433.82***
Return to scale Σb_i	0.820	1.211	1.651

ns = not significant; *significant at the 10 percent level of confidence; **significant at the 5 percent level of confidence; ***significant at the 1 percent level of confidence; figures within parentheses indicate standard error.

In intensive farming, the regression coefficient of feed cost was -0.191 which was significant at the 1 percent level. It implies that 1 percent increase in the cost of feed, keeping other factors constant, would decrease gross revenue by 0.191 percent. However, in semi-intensive and traditional farming estimated coefficients of feed cost were 0.231 and 0.365 respectively, which indicates that there is enough scope to increase the gross revenue by spending additional amount of feed in these farming systems.

The production coefficient of fertilizer cost was also negative in intensive farming (-0.169) which indicates that 1 percent increase in the cost of fertilizer, keeping other factors constant, would decrease gross revenue by 0.169 percent. However, in semi-intensive farming, the regression coefficient (0.115) was significant at the 5 percent level which implies that 1 percent increase in the cost of fertilizer, keeping other factors constant, would increase gross revenue by 0.115 percent. Similarly an increase of 1 percent cost of the fertilizer, remaining other factors constant would result in an increase of gross income by 0.434 percent in traditional farming.

The summation of all the production coefficients (Σb_i) in semi-intensive pangas farming is equal to 1.211 which is greater than 1. This means that the function exhibits increasing returns to scale; that is, if all the inputs specified in the function are increased by a certain percentage, farm income will increase by a larger proportion. In the example above, if all inputs are increased by 1 percent, income will increase by 1.211 percent in semi-intensive farming. Similarly, if all inputs are increased by 1 percent income will increase by 1.651 percent in traditional farming as the summation of all the production coefficients (Σb_i) is equal to 1.651. However, the summation of all the production coefficients (Σb_i) in intensive farming is equal to 0.820 which is lower than 1. This means that production function for intensive framing system exhibits decreasing return to scale.

From the Cobb-Douglas production function model, most of the included variables (except labour cost) were significantly effective on farm production as well as income in different farming systems. There is a positive effect of these factors in semi-intensive and traditional systems. Return to scale indicates that there are enough scopes to increase the production and income from pangas farms in semi-intensive and traditional systems.

4. CONCLUSIONS

The study shows that sutchi catfish (*P. hypophthalmus*) production is fully dependent on quality feed and other factors (i.e. farm size, stocking rate, fertilization and management skill), the importance of feed increases with the intensification of pangas culture. Feed costs generally constitute the highest single operational costs of traditional, semi-intensive and intensive grow-out farming. It is therefore essential that the feed should achieve maximum efficiency in terms of pangas production per unit cost. However, feed cost appears to be one of the major constraints against the greater expansion of pangas farming. The relative importance of production and feed conversion efficiency fully depend upon the quality and cost of feed in relation to the market value of the farmed product. The unit cost of various types of feed and cost of fish production using each of this feed as well as the unit profitability of each system of pangas production must be compared before one type of feed is selected. It is therefore of great importance to the pangas farmers to utilize feed as optimally as possible.

Higher production levels of pangas among intensive, semi-intensive and traditional farms have consequently activated their high acceptable levels of financial and economic indicators. As such, their estimated coefficients such as gross revenues, net returns, and benefit-cost ratios have reached the levels that are considered relatively financially and economically sound. The Cobb-Douglas production function indicates that there is enough scope to increase the production and income from semi-intensive and traditional systems by more inputs of fry, feed, and fertilizer. However, intensive farming system exhibits decreasing return to scale.

For sustainable pangas farming, the development of low-cost fish feed is essential to reduce the current, heavy dependence on industrially manufactured pelleted feed which has been the standard feed since the inception of intensive pangas cultivation. Farmers are at a turning point in their pangas feeding strategies due to the high price of this feed. However, lack of knowledge and information make them uncertain about the application of other feeds. In which case, the best alternative is farm-made aquafeed. Development of a feed based on low-cost locally produced ingredients would help improve farmer's profit margins. In addition, farmers need to extend their basic knowledge and develop better skills in integrated pangas farming with carps and dike cropping. Training and extension services would help to improve profitability and reduce risks. Although traditional farmers are aware of the positive effects of commercial feeds on their farm operation, lack of capital has prevented them from engaging in semi-intensive feeding practice. It is also essential that adequate credits with low interest are provided by the government as well as national banks to the farmers. This is particularly the case for traditional farmers so that they can shift from low density to high density culture, i.e. traditional to semi-intensive farming systems.

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