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The ICLARM-CLSU integrated animal-fish farming project: poultry-fish and pig-fish trials

FRESHWATER AQUACULTURE CENTER - CENTRAL LUZON STATE UNIVERSITY
INTERNATIONAL CENTER FOR LIVING AQUATIC RESOURCES MANAGEMENT

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1981

FRESHWATER AQUACULTURE CENTER-CENTRAL LUZON STATE UNIVERSITY
MUÑOZ, NUEVA ECIJA, PHILIPPINES

INTERNATIONAL CENTER FOR LIVING AQUATIC RESOURCES MANAGEMENT
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Cover: Aerial view of the CLSU Freshwater Aquaculture Center facilities. ICLARM-CLSU project ponds are in the foreground.

Preface

The two papers in this report contain the progressive results of experiments in integrated animal-fish farming at the Freshwater Aquaculture Center of the Central Luzon State University (CLSU), Muñoz, Nueva Ecija, Philippines, from 1978 to 1980.

The project is being carried out by scientists from CLSU and ICLARM under a cooperative agreement between the two institutions to (1) develop a fish polyculture system that will provide the highest economic return under conditions of manuring only, (2) determine the optimum numbers of pigs or poultry per unit area of pond, (3) clarify the economics of production and (4) design and package a technology for integrated farming appropriate to rural development in the Philippines.

The first paper, on pig-fish and duck-fish tests, was presented at the ICLARM-SEARCA Conference on Integrated Agriculture-Aquaculture Farming Systems, held in Manila, August 1979; the second was presented at the International Symposium on Biogas, Microalgae and Livestock Wastes, Taipei, Taiwan, September 1980.

The project is continuing, and a final report will be published in this series.

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Contents

Preliminary Results of Integrated Pig-Fish and Duck-Fish Production Tests*

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Abstract

Pig-fish and duck-fish production trials are described using 40 or 60 pigs/ha and 750 or 1,250 ducks/ha of pond surface, with total fish stocking densities of 10,000 or 20,000/ha (85% *Sarotherodon niloticus,* 14% *Cyprinus carpio* and 1% *Ophicephalus striatus*). The highest net yields were obtained with the 60 pig/20,000 fish and 750 ducks/20,000 fish combinations: 1,950 kg/ha and 1,690 kg/ha, respectively, from 90-day culture periods. Comparisons with control ponds receiving inorganic fertilization and measurements of water quality parameters (pH, dissolved oxygen and ammonia) are included.

Introduction

The rising cost of high protein fish feed and inorganic fertilizer, as well as the general concern for energy conservation, have brought about increased interest in the utilization of animal manures in aquaculture and in the traditional systems which integrate animal husbandry with aquaculture.

Recent experiments have demonstrated that considerable fish production can be obtained when animal manures are properly applied to fish polyculture systems. Moav et al. (1977) reported a daily gain of 35 kg/ha (8 t/ha/240 days) from a fish polyculture system (silver carp, common carp, grass carp and tilapia) receiving liquified cowshed manure. Polyculture of carps, channel catfish and largemouth bass, with wastes from 66 pigs/ha as the only source of nutrients, yielded 4 t/ha/yr (Buck et al. 1978). A daily yield of 32 kg/ha (7.6 t/ha/240 days) was achieved in ponds receiving only duck droppings (Wohlfarth 1978) and supplementary addition of chicken droppings under conditions of intensive fish culture increased fish yield by 21% and decreased the feed conversion rate by 0.4 units (Rappaport and Sarig 1978). Similar findings reported in earlier literature were reviewed by Woynarovich (1979).

Much of this information is germane to temperate and/or subtropical climates. Although integrated animal-fish farming has a long history in Southeast Asia, production methods are not well documented, if at all, and formal experimentation is only just beginning. Furthermore, the classic polyculture systems used are based on Chinese or Indian carps, which are either not marketable or fetch low prices in some countries like the Philippines.

*Reprinted from Pullin, R.S.V. and Z.H. Shehadeh, Editors. 1980. Integrated agriculture-aquaculture farming systems. ICLARM Conference Proceedings 4, 258 p. International Center for Living Aquatic Resources Management, Manila, and the Southeast Asian Regional Center for Graduate Study and Research in Agriculture, College, Los Baños, Laguna, Philippines.

In the case of the Philippines (Central Luzon), where average farm size is less than 3 ha (Sevilleja & McCoy 1979), integrated animal-fish farming could be an appropriate means for increasing returns from a limited land area and reducing risk by diversifying crops. However, before a development effort can be mounted to popularize animal-fish farming, available production methods need to be adapted to the prevailing tropical climate and locally marketable fish species, and the economic viability of the system needs to be ascertained.

Accordingly, a research project was initiated in 1977 at the Freshwater Aquaculture Center (FAC) of the Central Luzon State University (CLSU), to 1) design a fish polyculture system that would provide the highest economic return, giving manure as the only nutrient source, 2) determine the maximum pig or duck stocking rate per unit area of freshwater fish pond, and 3) clarify the economics of the developed production system(s). This paper presents the preliminary findings from the first 180 days of a series of production tests.

Methodology

A special facility was constructed consisting of 12 ponds each of 1,000 m^2 area for the pig-fish tests and 12 ponds each of 400 m^2 for the duck-fish tests with the animal pens on top of the dikes (Figure 1).

The tests were run for 180 days, which corresponds to the pig rearing period from weaned piglet to market size (finished) pig. The ducks were grown as layers and kept in the pens for the same period of time. Two fish production tests of 90 days each were conducted during this period, as the preferred tilapia market size in Central Luzon (60 g) can be attained or surpassed in 90 days at the FAC.

The factorial experimental design consisted of two animal stocking rates of 40 and 60 pigs/ha; 750 and 1,250 ducks/ha. Fish production in conjunction with each animal stocking rate was tested at stocking densities of 10,000 and 20,000 fish/ha with manure as the only input. Two control ponds received only inorganic fertilizer (N:P:K, 16:20:0) at the

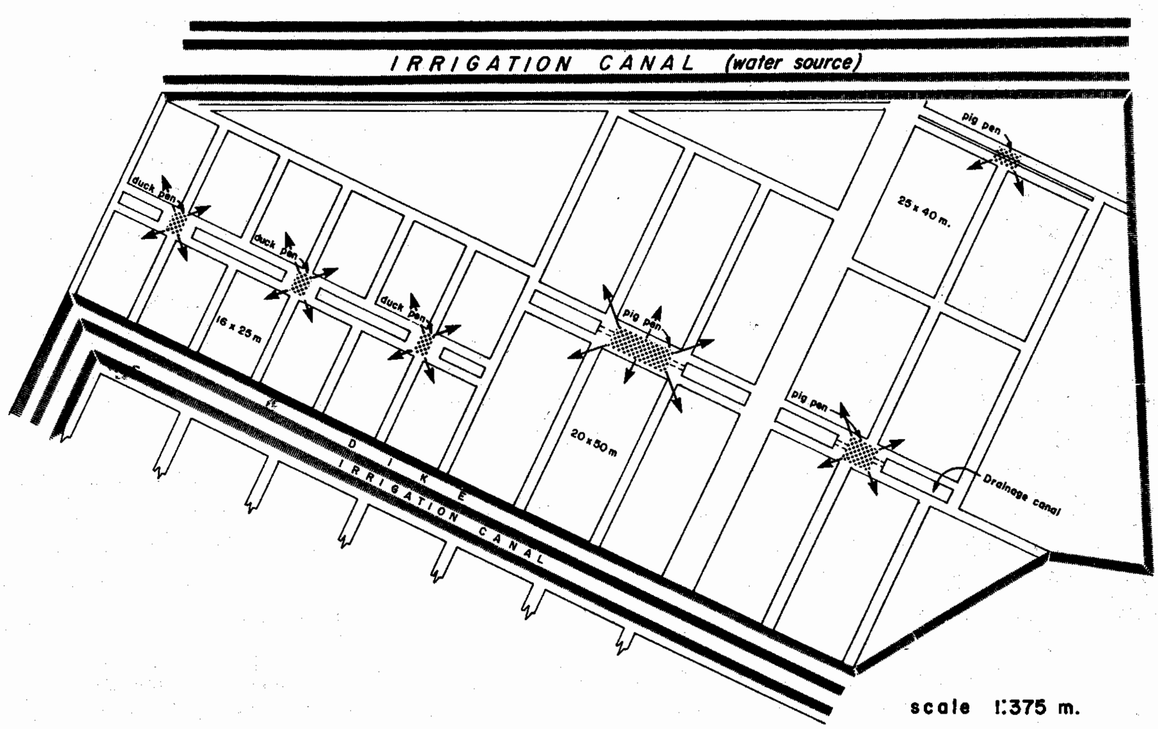

Figure 1. Layout of the experimental facility showing the relationship of animal pens to fish ponds. Arrows indicate waste delivery.

rate of 50 kg/ha every 15 days. Each combination was duplicated during the first 90-day fish production period and replicated three times during the second 90-day period.

Weaned piglets (Large White-Landrace cross) weighing 18 to 20 kg each, and Pekin ducks of 500 to 700 g were fed and managed according to standard procedures recommended for the Philippines (PCARR 1976, 1977). Manure from pig pens was washed into the ponds via narrow concrete canals, while duck droppings were collected and broadcast on the ponds. In both cases, manure was dispensed to the ponds daily at 8:00 to 10:00 a.m. The ducks were allowed to graze on the ponds daily and nylon screens inside the ponds protected the dikes from their foraging activities.

The fish species and densities used were:

Sarotherodon niloticus (Nile tilapia)	8,500 /ha	17,000 /ha
Cyprinus carpio (common carp)	1,400	2,800
Ophicephalus striatus (snakehead or mudfish) a tilapia predator	100	200
	10,000 /ha	20,000 /ha

The growth of fish, pigs and ducks was monitored every other week. Dissolved oxygen and water temperature were recorded with an oxygen/temperature meter (Yellow Springs Instruments; YSI 54 AR) at 6:30 a.m. on alternate days. Early morning ammonia-ammonium concentration was determined weekly with a specific ion meter (Orion, Model 47A) and an ammonia electrode (Orion, 95-10). All readings were taken at a depth of 0.5 m in three locations along the long axis of the ponds and a mean value calculated. Fish were harvested at the end of each culture period by draining the ponds and fish recovery rates, production and other pertinent growth data recorded.

Results

A. PIG-FISH TESTS

1. First 90-day Test Period (Table 1, Figure 2)

Net fish yields increased with pig stocking rates and fish density to a maximum of 958 kg/ha (10.7 kg/ha/day), with tilapia and carp mean weights of 43 and 80 g, respectively, from the 60 pigs-20,000 fish/ha combination. Control ponds receiving inorganic fertilizer produced a maximum of 560 kg/ha (6.2 kg/ha/day) which is roughly equivalent to the yield from ponds with 40 pigs and between 10,000 and 20,000 fish/ha, and to 58% of the yield from the 60-20,000 combination.

The growth rate of tilapia (Figures 3, A & B) increased with pig stocking rates and decreased as fish density increased. A maximum final mean weight of 73 g was obtained with the 60-10,000 combination. Individual mean weights from other combinations were 54 g or less. Tilapia growth levelled off at a mean weight of 35 g in the 40-20,000 combination indicating that maximum carrying capacity was reached at the given fish stocking densities and pig biomass (manure delivery). Growth also levelled off in control ponds at mean weights of 52 and 33 g at the low and high fish densities respectively after 60 days and began to decrease towards the end of the culture period.

Final individual mean weight of carp was also highest (149 g) in the 60-10,000 combination (it was not possible to follow carp growth because the fish evaded sampling nets

Table 1. Fish production *(Sarotherodon niloticus, Cyprinus carpio* and *Ophicephalus striatus)* in pig-manured ponds during the first 90-day test period (September-November 1978). Production figures represent means of duplicate ponds.

Pigs/ha	Species	Stocking fish/ha	Individual mean weight (g) Initial	Final	Gain (g)	Average daily gain (g)/fish	Recovery %	Yield (kg/ha) in 90 d
0 (control)[1]	*S. niloticus*	8,500	6.7	48.7	42.0	0.5	90.4	376.1
	C. carpio	1,400	12.2	119.2	107.0	1.2	100.0	176.1
	O. striatus	100	1.0	165.8	164.8	1.8	45.0	7.5
	Total	10,000				3.5		559.7
0 (control)[1]	*S. niloticus*	17,000	3.8	26.7	22.9	0.3	78.5	357.0
	C. carpio	2,800	3.4	22.7	19.3	0.2	100.0	78.6
	O. striatus	200	1.0	97.5	96.5	1.1	65.0	10.5
	Total	20,000				1.6		446.1
40	*S. niloticus*	8,500	4.0	53.6	49.6	0.6	72.8	329.0
	C. carpio	1,400	3.2	109.4	106.2	1.2	100.0	155.0
	O. striatus	100	1.0	161.9	160.9	1.8	45.0	7.1
	Total	10,000				3.6		491.1
40	*S. niloticus*	17,000	4.5	35.1	30.6	0.3	92.5	552.4
	C. carpio	2,800	4.6	46.0	41.4	0.5	90.5	116.7
	O. striatus	200	1.0	167.7	166.7	1.9	80.0	13.4
	Total	20,000				2.7		682.5
60	*S. niloticus*	8,500	4.9	73.2	68.3	0.8	87.3	542.0
	C. carpio	1,400	4.7	149.3	144.6	1.6	100.0	209.5
	O. striatus	100	1.0	200.0	199.0	2.2	25.0	4.9
	Total	10,000				4.6		756.4
60	*S. niloticus*	17,000	2.5	43.1	40.6	0.5	72.2	742.0
	C. carpio	2,800	3.0	80.1	77.1	0.9	97.0	195.7
	O. striatus	200	1.0	186.1	185.1	2.1	90.0	20.5
	Total	20,000				3.5		958.2

[1]Inorganic fertilizer NPK (16-20-0) applied @ 50 kg/ha/15 days.

successfully). Carp yields from the 60-10,000 and 60-20,000 combinations were identical, indicating that the carrying capacity for carp at the given fish and pig stocking rates was reached.

Although the 60-20,000 combination gave the highest fish yield, the 60-10,000 combination could prove more profitable if significantly higher prices can be obtained for larger fish. Another point worth noting from the comparison of yields from control ponds and those receiving manure from 40 pigs is that a 40-15,000 combination would result in savings equal to the price of 300 kg of 16:20:0 fertilizer over 90 days.

Initial and final individual mean weights of pigs for the 90-day period were about 20 and 52 kg, respectively (Table 3).

2. Second 90-day Test Period (Table 2, Figure 2)

Since this test series was initiated with pigs of about 56 kg mean weight (Table 3) carried over from the first test period, as compared to 20 kg mean weight in the latter,

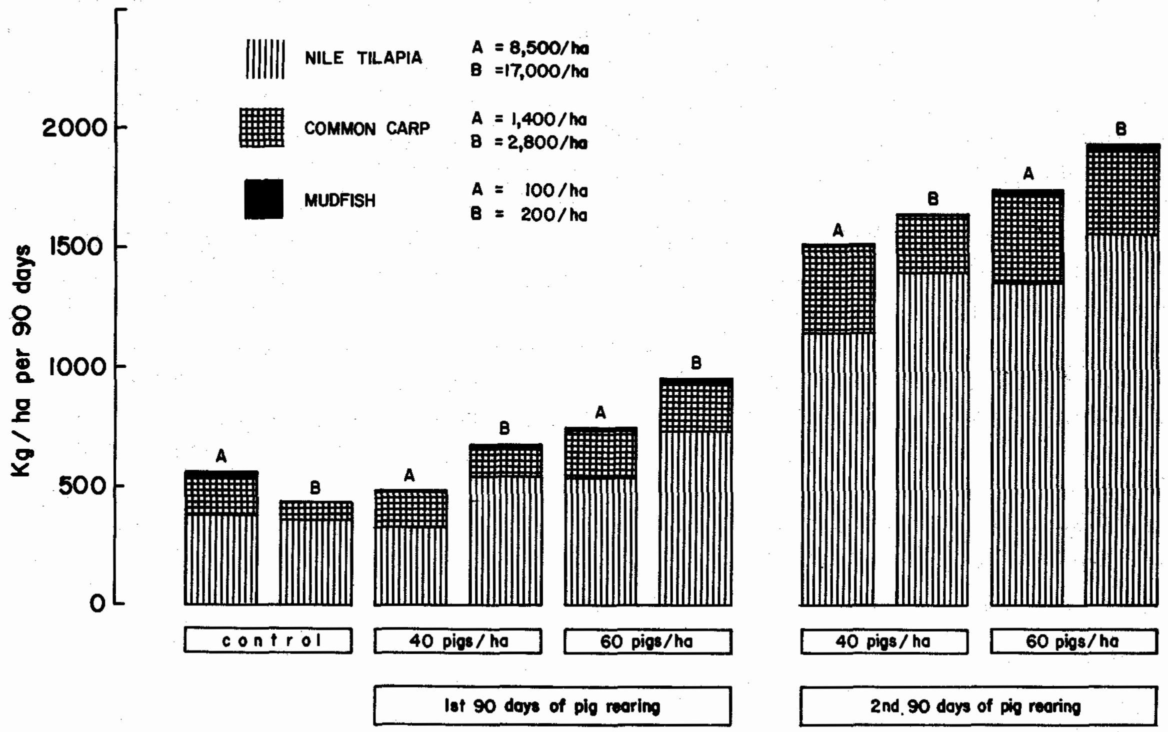

Figure 2. Individual and cumulative net yields of nile tilapia *(Sarotherodon niloticus)*, common carp *(Cyrpinus carpio)* and mudfish *(Ophicephalus striatus)* cultured together for 90-day periods in ponds receiving pig manure. The columns represent the means from duplicate ponds over the 1st 90 days and triplicate ponds over the 2nd 90 days.

Table 2. Fish production *(Sarotherodon niloticus, Cyprinus carpio* and *Ophicephalus striatus)* in pig-manured ponds during the second 90-day test period (January-March 1979). Production figures represent means of triplicate ponds.

Pigs/ha	Species	Stocking fish/ha	Individual mean weight (g) Initial	Final	Gain (g)	Average daily gain (g)/fish	Recovery %	Yield (kg/ha) in 90 d
40	*S. niloticus*	8,500	3.7	166.1	162.4	1.8	83	1,156
	C. carpio	1,400	71.4	344.7	273.3	3.0	73	356
	O. striatus	100	103.6	263.0	159.4	1.8	27	8
	Total	10,000				6.6		1,520
40	*S. niloticus*	17,000	2.8	92.0	89.2	1.0	90	1,408
	C. carpio	2,800	71.4	166.5	95.2	1.1	52	253
	O. striatus	200	103.6	238.3	134.8	1.5	25	11
	Total	20,000				3.6		1,672
60	*S. niloticus*	8,500	3.2	160.5	157.2	1.7	100	1,364
	C. carpio	1,400	71.4	358.8	287.4	3.2	75	373
	O. striatus	100	103.6	217.8	114.2	1.3	50	11
	Total	10,000				6.2		1,748
60	*S. niloticus*	17,000	3.9	119.9	115.9	1.3	78	1,576
	C. carpio	2,800	71.4	181.1	109.7	1.2	71	353
	O. striatus	200	103.6	305.3	201.7	2.2	35	21
	Total	20,000				4.7		1,950

both fish growth rates and net yields were expected to be higher due to increased manure delivery.

As can be noted from Table 2 and Figure 2, net yields again increased with pig and fish stocking rates to a maximum of 1,950 kg/ha (22 kg/ha/day), with tilapia and carp mean weights of 119 and 181 g, respectively, from the 60-20,000 combination.

Tilapia growth rates (Figure 3C) followed the same pattern as in the first test period. A maximum mean weight of 166 g was obtained from the 40-10,000 combination, as compared to 120 g from 60-20,000 combination. Tilapia growth did not level off in any of the test combinations indicating that the manure delivery rate did not limit growth as in the case of the 40-20,000 combination in the first 90-day period. However, at fish densities of 10,000/ha, tilapia growth did not increase with increased pig stocking rate. This indicates that at 60 pigs/ha, more food was produced than could be utilized by the fish biomass.

Carp yield was highest (370 kg/ha) in the 60-pig combinations but was essentially the same at both fish densities, indicating that the carrying capacity for carp was reached with 60 pigs.

Initial and final individual mean weights of pigs during the second 90-day culture period were 57 and 102 kg, respectively (Table 3).

3. Water Quality

Early morning (6:30 a.m.) water temperature was 25 to 29°C (minimum-maximum) during the first 90-day test period (September to November) and 21 to 27°C during the second period (January to March). pH varied between 7.5 to 9 in control ponds and pig-fish ponds during the first period and between 8 and 9 in pig-fish ponds during the second period. There were no discernible differences in pH between the various pig-fish combinations during either test period.

Special attention was paid to dissolved oxygen concentrations in pond water as an indicator of manure overloading, particularly during the second test period when water temperature was lower and manure loading higher than in the first period. Early morning dissolved oxygen (Figure 4) varied between 3 and 8 ppm in control ponds. Fish density and pig stocking rates did not affect oxygen concentrations in either test period. Concentrations in pig-fish ponds during the first period began to decrease steadily from control values on the 66th day but remained above 3 ppm. During the second period, oxygen values declined steadily, after one month, from 5 to 1.2 ppm (Figure 4). Ammonia-ammonium concentrations in the second test period increased gradually from 0.22 to 0.35 ppm in all combinations except the 60-20,000 set where a final concentration of 0.78 ppm was recorded.

B. DUCK-FISH TESTS

1. First 90-day Test Period (Table 4, Figure 5)

The results of this test were not as clearcut as the equivalent pig-fish tests because a substantial amount of duck manure was deposited on the dikes and did not reach the ponds, and due to the influence of a typhoon on duck health and growth. The manure problem was eliminated in the second test period with a fence which excluded access to the dikes.

The same general trends noted in the pig-fish tests were nevertheless evident. Yields tended to increase with duck and fish stocking rates to a maximum of 980 kg/ha (10.9 kg/

Table 3. Change in individual mean weights of pigs during the two 90-day test periods.

Combination (pig-fish/ha)	Initial	2	4	6	8	10	12
A. First test period							
40-10,000	19.77	23.95	27.30	32.72	37.50	48.57	53.97
40-20,000	18.67	22.10	26.06	32.92	36.30	47.42	51.80
60-10,000	18.54	22.09	25.46	30.28	34.46	44.08	49.94
60-20,000	19.68	22.35	25.11	30.40	39.08	50.65	56.61
B. Second test period							
40-10,000	61.25	68.66	79.66	85.91	94.58	99.33	105.75
40-20,000	50.60	58.98	69.33	78.66	87.66	93.66	100.91
60-10,000	55.15	63.27	71.99	81.72	89.05	97.16	103.88
60-20,000	60.02	66.18	72.91	82.35	87.88	92.86	97.02

Time (wk) applies to columns 2–12.

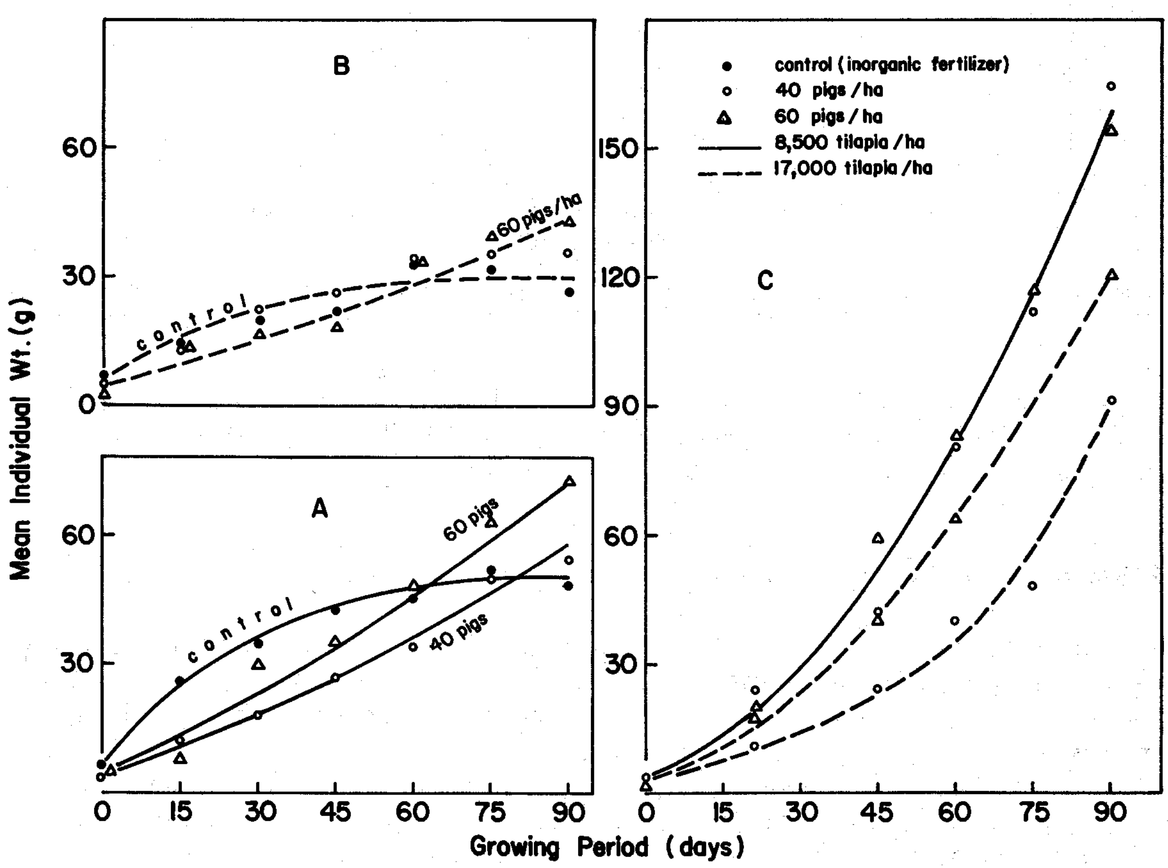

Figure 3. Growth rates of *Sarotherodon niloticus* at two stocking densities in ponds receiving pig manure: A—mean individual weights of fish stocked at 8,500/ha in duplicate 0.1-ha ponds receiving manure from 40 and 60 pigs/ha during the 1st 90 days of a pig production cycle and inorganic fertilizer (NPK: 16:20:0) for comparison. B—as A but with 17,000 fish/ha comparing 60 pigs/ha and inorganic fertilization. C—as A and B but with triplicate ponds during the 2nd 90 days of the pig production cycle with no inorganic fertilization for comparison.

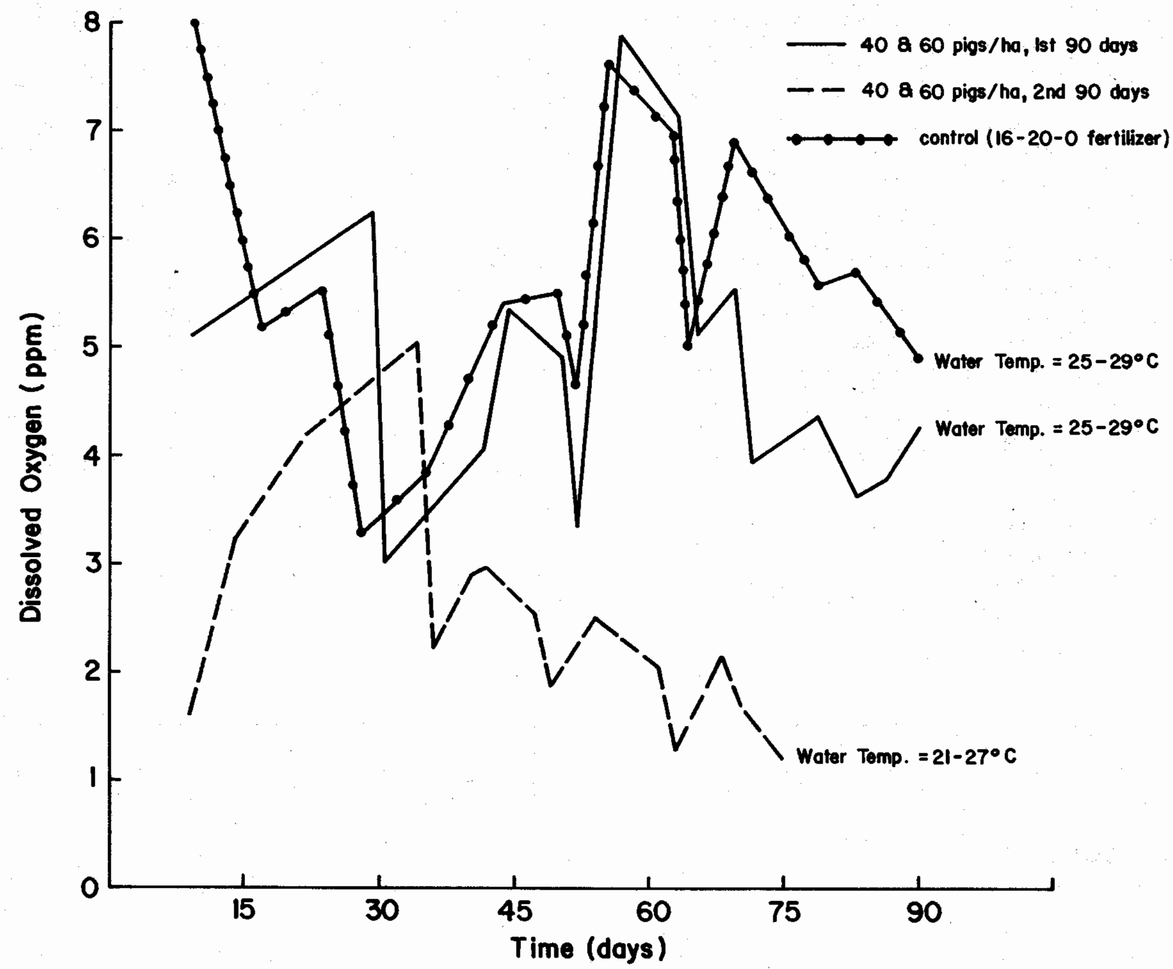

Figure 4. Early morning (6:30 a.m.) dissolved oxygen in ponds receiving pig manure during two consecutive 90-day periods. Data represent mean values from duplicate ponds for the 1st 90 days; controls and triplicate ponds for the 2nd 90 days.

ha/day), with tilapia and carp mean weights of 60 and 96 g, respectively, from the 1,250 ducks-20,000 fish combination. Fish yield from the 750-10,000 combination matched production from control ponds with the same fish density.

2. Second 90-day Test Period (Table 5, Figure 5)

Maximum fish yield of about 1,690 kg/ha (18.8 kg/ha/day), with mean tilapia and carp weights of 98 and 213 g, respectively, was obtained in this test series from the 750-20,000 combination. Yields from ponds with duck stocking rates of 1,250/ha gave lower yields than those with 750 ducks/ha at both fish densities.

The growth curves of tilapia (Figure 6) demonstrate depressed growth at the higher duck stocking rate. Carp production, however, was highest (402 kg/ha) from the 1,250-20,000 combination despite prevailing low oxygen concentrations.

3. Water Quality

Early morning water temperature was 23 to 28°C and 21 to 28°C during the first and second test periods, respectively. pH was 7 to 8 in both periods. Early morning dissolved oxygen declined steadily during both test periods but remained above 2 ppm throughout the first period. During the second period, however, oxygen values were below 2 ppm most of the time, declining to less than 1 ppm towards the end of the period. Ammonia-ammonium concentrations in the second test period increased gradually from 0.19 to 0.30 ppm in all combinations except the 1,250-20,000 set in which concentrations rose to 0.52 ppm.

Tentative Conclusions

In spite of the preliminary nature of the data, some tentative conclusions can be reached:

A. PIG-FISH TESTS

1. The results clearly indicate that 60 pigs-20,000 fish/ha provide the highest net yield of fish. As indicated in the text, maximum yield may not correspond with maximum economic return. Much will depend on size-related market price for fish. If a premium is paid for larger fish, then stocking rates must be reduced with a resulting decrease in total net yield. At present, mixed sizes of tilapia are marketed in Central Luzon at a wholesale price of ₱*6/kg while carp fetches about ₱3 to 4/kg. This may change in the future.

2. Assuming for the moment that maximum production and profitability are synonymous, annual fish production with the 60-20,000 combination will depend on the management method used. For example, if pigs are grown from 20 to 100 kg over the pond, then a net yield of 958 + 1,950 = 2,908 kg/ha can be achieved in one pig rearing cycle of 180 days. To this can be added the fish yield (958 kg/ha) from another 90-day period with new pigs to make a total production of 3,866 kg/ha in 270 days. It is evident from our data, however, that fish production during the first 90 days of pig rearing is low due to inadequate manure production, and that doubling the pig biomass during this period would double the fish yield resulting in annual fish production of 1,950 x 3 = 5,850 kg/ha in 270 days.

If adjustment of pig biomass is not feasible, an alternative would be to increase fish production during the initial 90 days with supplemental feed (rice bran).

3. Since dissolved oxygen concentrations were about one ppm during the end of the second 90-day pig rearing period at 60 pigs-20,000 fish/ha, it appears likely that a further increase of pig stocking rate will either reduce fish production or cause fish mortality during the last 90 days of the pig rearing period.

B. DUCK-FISH TESTS

Following the same argument outlined above, and assuming Pekin ducks are raised as layers, then the recommended maximum duck-fish stocking rate is 750-20,000. Maximum net fish yield, after ducks have become regular layers, would be 1,690 kg/ha/90 days, or 5,070 kg/ha in 270 days.

C. FISH COMPOSITION

The above recommendations are based on a fish composition of 85% nile tilapia, 14% common carp and 1% mudfish. This composition was used because fry of these fish can be

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*₱7.5 = US$1.00.

Table 4. Fish production *(Sarotherodon niloticus, Cyprinus carpio* and *Ophicephalus striatus)* in duck-manured ponds during the first 90-day test period (October-December 1978). Production figures represent means of duplicate ponds.

Ducks/ha	Species	Stocking fish/ha	Individual mean weight (g) Initial	Final	Gain (g)	Average daily gain (g)/fish	Recovery %	Yield (kg/ha) in 90 d
750	*S. niloticus*	8,500	1.8	69.0	67.2	0.8	76.6	395.0
	C. carpio	1,400	2.3	165.0	162.7	1.8	100.0	196.8
	O. striatus	100	1.0	150.0	149.0	1.7	87.5	9.4
	Total	10,000				4.3		601.2
750	*S. niloticus*	17,000	2.1	61.9	59.8	.7	59.9	489.5
	C. carpio	2,800	2.3	61.2	58.9	.7	95.5	225.3
	O. striatus	200	1.0	135.0	134.0	1.5	37.5	16.0
	Total	20,000				2.9		730.8
1,250	*S. niloticus*	8,500	2.0	71.5	69.5	.8	85.0	502.0
	C. carpio	1,400	2.3	134.3	132.0	1.5	83.9	166.2
	O. striatus	100	1.0	179.9	178.9	2.0	91.7	16.3
	Total	10,000				4.3		684.5
1,250	*S. niloticus*	17,000	2.1	59.7	57.6	.6	61.0	679.0
	C. carpio	2,800	2.3	95.7	93.4	1.0	92.0	290.8
	O. striatus	200	1.0	96.9	95.9	1.1	43.7	9.8
	Total	20,000				2.7		979.6

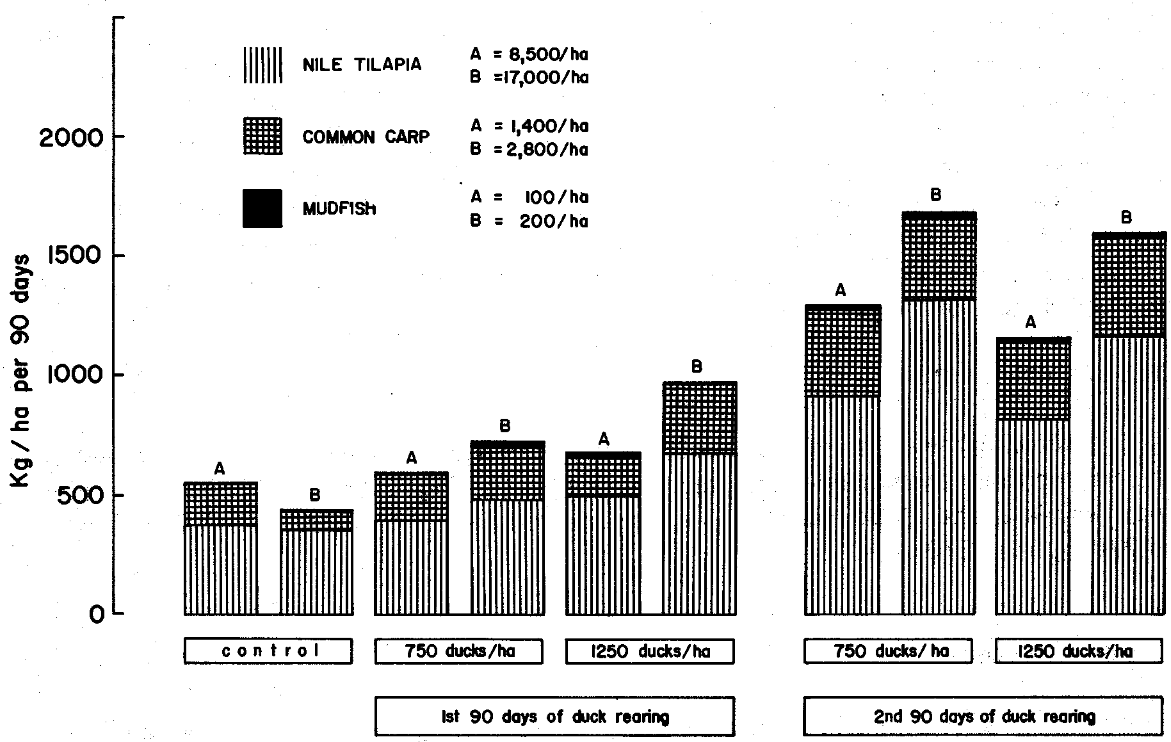

Figure 5. Individual and cumulative net yields of nile tilapia *(Sarotherodon niloticus)*, common carp *(Cyrpinus carpio)* and mudfish *(Ophicephalus striatus)* cultured together for 90-day periods in ponds receiving duck manure. The columns represent the means from duplicate ponds over the 1st 90 days and triplicate ponds over the 2nd 90 days.

Table 5. Fish production *(Sarotherodon niloticus, Cyprinus carpio* and *Ophicephalus striatus)* in duck-manured ponds during the second 90-day test period (January-March 1979). Figures represent means of triplicate ponds.

Ducks/ha	Species	Stocking fish/ha	Individual mean weight (g) Initial	Final	Gain (g)	Average daily gain (g)/fish	Recovery %	Yield (kg/ha) in 90 d
750	*S. niloticus*	8,500	2.0	121.6	119.6	1.3	90.5	920.3
	C. carpio	1,400	54.5	378.2	323.7	3.6	75.0	368.8
	O. striatus	100	33.7	276.7	243.0	2.7	46.7	15.2
	Total	10,000				7.6		1,304.3
750	*S. niloticus*	17,000	2.0	97.6	95.6	1.1	81.8	1,323.3
	C. carpio	2,800	51.0	213.0	162.0	1.8	61.6	345.8
	O. striatus	200	34.7	232.7	198.0	2.2	37.5	20.5
	Total	20,000				5.1		1,689.6
1,250	*S. niloticus*	8,500	2.0	106.9	104.9	1.2	88.8	824.5
	C. carpio	1,400	56.7	299.7	243.0	2.7	66.7	323.8
	O. striatus	100	39.0	300.0	261.0	2.9	8.3	15.0
	Total	10,000				6.8		1,163.3
1,250	*S. niloticus*	17,000	2.0	90.4	88.4	1.0	79.3	1,174.5
	C. carpio	2,800	48.3	273.3	225.0	2.5	63.7	402.0
	O. striatus	200	40.0	211.0	171.0	1.9	50.0	21.5
	Total	20,000				5.4		1,598.0

produced or obtained by farmers in the Philippines fairly easily. However, this system is unstable because it does not include efficient filter feeders. There is particular need to add a nannoplankton feeding fish, like the silver carp *(Hypophthalmichthys molitrix)*, to control phytoplankton populations (especially in the duck ponds). The addition of such fish to the system can be expected to increase net yield and reduce oxygen stress. Since silver carp is not marketable in the Philippines, milkfish *(Chanos chanos)* will be added to the system in future tests.

Experiments will also be conducted to test the feasibility of replacing most of the common carp with *Sarotherodon aureus* which is mostly a bottom feeder and would fetch a higher price than carp.

D. FISH GROWING PERIOD

Stocking and draining of fish ponds every 90 days is not practical. It wastes labor, growing time and water. Furthermore, animal wastes cannot be turned into the pond during drainage and harvest operations. The fish growing period should at least match the animal rearing period. Optimally, ponds should be drained only once per year.

E. ENVIRONMENTAL IMPACT

Future tests in this project will include measurements of BOD_5 and nitrogen and phosphorous concentrations in water drained from fish ponds in order to assess the pollution hazard from this effluent. Consideration will also be given to setting aside a small pond area

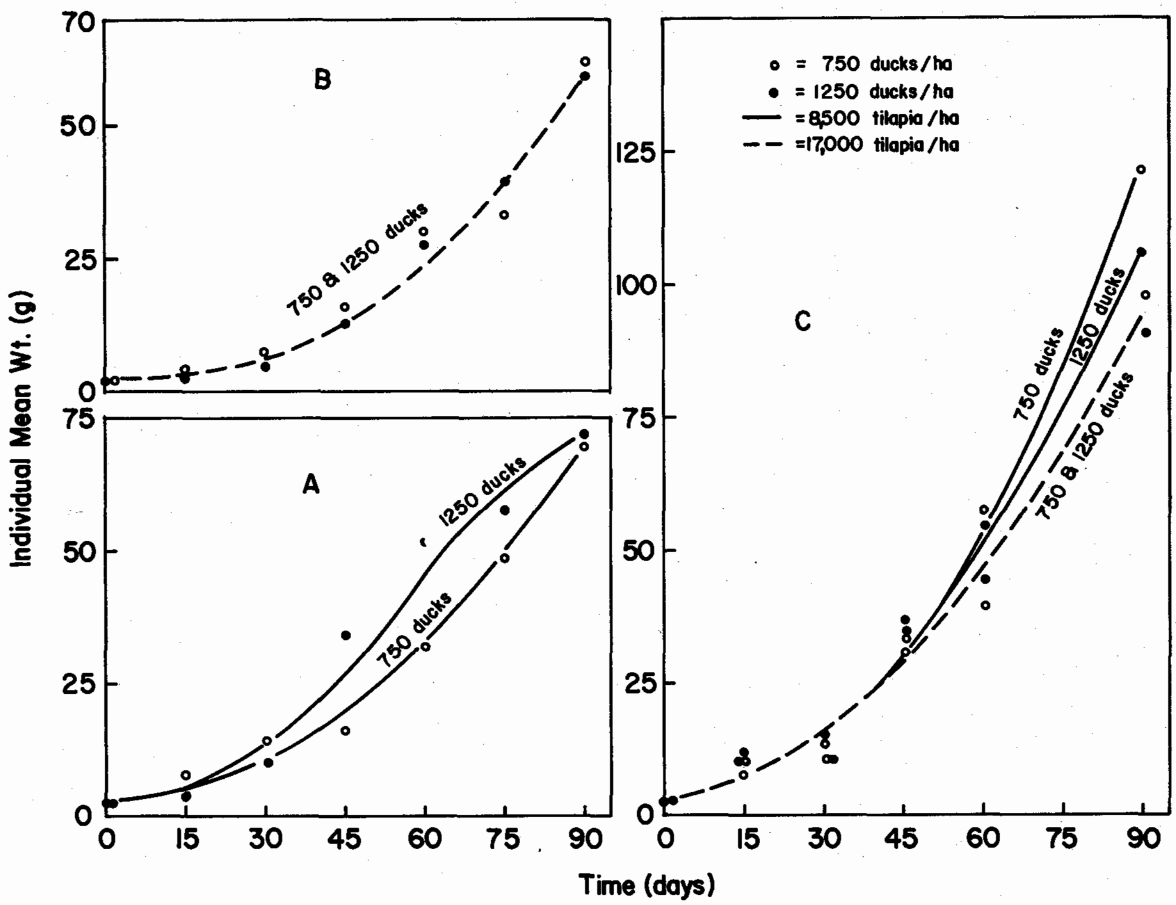

Figure 6. *Sarotherodon niloticus* stocked at two densities in ponds, receiving duck manure: A—mean individual weights of fish stocked at 8,500/ha in duplicate 0.04-ha ponds receiving manure from 750 and 1,250 ducks/ha during the 1st 90 days of a duck production cycle. B—as A but with 17,000 fish/ha. C—as A and B but using triplicate ponds receiving manure during the 2nd 90 days of a duck production cycle.

as a receptacle for animal manure during harvest/restocking operations. Such a pond could be stocked with airbreathing fish, such as *Clarias* spp. or *Ophicephalus striatus.*

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Optimum Manure Loading Rates in Tropical Freshwater Fish Ponds Receiving Untreated Piggery Wastes*

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Abstract

Manure from grower-finisher pigs (15-100 kg) was added to 0.1 ha ponds at six different rates: 40, 60, 80, 100, 120 and 140 pigs/ha of pond. Tilapia *(Sarotherodon niloticus), Cyprinus carpio* and *Ophicephalus striatus* were cultured in the ponds at total stocking rates of 10,000 and 20,000 fish/ha. There were two 90-day fish culture periods in each 180-day pig culture period. The highest net fish yield of 3,549 kg/ha/180 days was obtained with 103 pig/ha and 20,000 fish/ha treatment. Based on the estimated production functions relating fish yield to manure input (number of pigs), optimum manure loading rates were computed for Philippine pig-fish operations at prevailing market prices.

Introduction

The use of animal manures in fish ponds has a very long history, particularly in China. However, it has only been in the last few years that the need to conduct research on manure loading of fish ponds has been recognized. The ever increasing cost of commercial fish feeds and the potential for high fish yields using manure as the only nutrient source are primary reasons for this. The proceedings of conferences on Fish Farming and Wastes (Pastakia 1980) and Integrated Agriculture-Aquaculture Farming Systems (Pullin and Shehadeh 1980), and the review by Wohlfarth and Schroeder (1979) present a large amount of information about the current status of manure utilization in fish ponds and research in this area.

Much of the technical literature on manure utilization in fish ponds has been concerned with temperate or subtropical countries using carps as the main species. Some notable exceptions are the use of cattle and pig manure for Tilapia culture in Brazil (Lovshin et al. 1974) and the use of pig manure for Tilapia culture in Africa (Nugent 1978) and Southeast Asia (Pullin and Shehadeh 1980). Except for the Brazil experiments, almost all of the literature dealing with manure utilization in tropical ponds are descriptions of practices.

In 1978, the International Center for Living Aquatic Resources Management (ICLARM) and the Freshwater Aquaculture Center (FAC) of Central Luzon State University, Philippines, started an integrated animal-fish research project to develop quantitative guidelines for pig-fish and poultry-fish culture systems in the Philippines. The preliminary results were

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presented by Cruz and Shehadeh (in this volume). A refinement of the preliminary results plus additional data are used herein to define the relationships of manure input to fish yield. These relationships (production functions) are then used with several sets of cost data to determine the optimum pig-pond surface area relationships for the Philippines.

Methods

Weaned piglets (10 to 14 kg) were grown to market size (90 to 100 kg) in animal pens constructed on top of the pond dikes. Each pen was connected to a pond by a short channel. Manure was washed from the pens into the ponds daily via the channels. The experiments were designed around the six-month pig growing cycle. There were two independent fish culture periods in each pig growing cycle since the fish attain marketable size (above 60 g) in just three months.

Commercially produced Large White-Landrace cross piglets were managed according to standard procedures recommended for the Philippines (PCARR 1976). The pigs were first fed a commercial starter ration until reaching an average weight of 20 to 25 kg, then a grower-ration up to 55 to 60 kg, and a finisher ration until marketing. The feeding rate was adjusted such that the pigs consumed all of the rations in two 30 minute feedings per day. This represents about 3 to 5% body weight per day. The weight of the pigs was determined biweekly. The amount of manure was also determined biweekly by plugging the drain pipe and collecting all the feces mixed with urine excreted during a 24-hour period. The manure was weighed and proximate analysis of thoroughly mixed samples were made periodically using standard methodologies.

The initial experiments were set up in factorial designs of 40, 60, 80 and 100 pigs/ha water surface. Two fish stocking rates, 10,000 and 20,000 fish/ha were planned. *Sarotherodon niloticus* were to comprise 85%, *Cyprinus carpio* 14% and *Ophicephalus striatus* 1% of the fish stocked. Tilapia fingerlings (1-6 g) were stocked at 8,500 and 17,000 per ha. The stocking rates of *Cyprinus carpio* varied from 720 to 2,800 fish/ha, due to problems with fingerling supply. *Ophicephalus striatus* fingerlings were stocked at 100-300/ha as a predator on unwanted Tilapia offspring. Actual stocking rates were approximately 9,300-10,000 fish/ha and 18,600-20,000 /fish ha. Table 1 shows the experimental design and number of replicates.

The fish ponds were 1,000 m^2 with average depths of 0.7 to 0.9 m. Water was taken from an irrigation canal adjacent to the project area. After filling, water was added only to

Table 1. Experimental design and number of replicates.

Approximate number of fish/ha	Number of pigs/ha	Number of replicates: First 90 day fish cycle	Number of replicates: Second 90 day fish cycle
10,000	40	2	3
	60	2	3
	80	3	3
	100	3	3
20,000	40	2	3
	60	2	3
	80	3	3
	100	3	3
	120	–	2
	140	–	2

replace losses due to seepage and evaporation. The alkalinity was approximately 120 mg/1 $CaCO_3$; water temperature was 33°C average maximum and 25°C average minimum.

Fish were harvested at the end of each 90-day fish culture period by draining the ponds. The weight of the marketable Tilapia and carp were determined.

After the initial experiments were completed, further experimentation with higher pig/manure levels was needed. However, the pig pens can hold a maximum of only ten pigs (100 pigs/ha). To test higher manure levels, fresh manure was procured from a nearby piggery and was added to 400 m^2 ponds at rates of 120 and 140 pigs/ha for the second 90-day period only. The amount of manure was based on observations made during the initial experiments. Twenty thousand fish/ha were grown in the small ponds for 75 days. Yield at 90 days was estimated by multiplying the 75-day yields by a constant of 1.25. This constant was derived from the ratio of sample weights at 75 days to yield at 90 days for the 100 pigs/ha treatments.

Production functions relating manure input to *S. niloticus* and *C. carpio* were estimated using regression techniques. The *O. striatus* production was not included because the recovery of this fish is highly variable as the fish tends to burrow into the mud when the pond is drained. Also, in a few ponds, the toxicant used in preparing the ponds did not decompose as rapidly as expected. Therefore, data from ponds in which survival was less than 50% were excluded from the analyses.

The relationships of number of pigs/manure and pond sizes which maximize profit and internal rate of return were determined for levee-type and excavated ponds each with gravity and pumped water systems. The production cycle was increased to eight months by including two months for harvest, renovation and repairs and restocking.

Cost of construction and operation of 11 sizes of freshwater ponds (100, 500, 1,000, 2,500, 5,000, 7,500, 10,000, 20,000, 30,000, 40,000 and 50,000 m^2) were estimated using price data collected in May and June, 1980. The pond sizes selected span the size range of practical Philippine freshwater fish ponds. Pond designs were based on accepted practice. Appendix Tables A-G contain the design parameters and cost estimates.

Eleven budgets, one for each pond size, were made for each pond type and water system. An example budget is presented in Table 2. No costs were assigned to the manure because at present there is no market for pig manure in most of the Philippines. Costs were calculated for all labor requirements. Labor costs were not ignored for small-scale or back-yard operations even though the labor used is minimal. This labor is usually provided by the farmer's friends in exchange for fish. The relationships of size to both total fixed costs (TFC) and total variable cost (TVC) were estimated using regression techniques. One set of equations for the smaller pond sizes and another for the larger pond sizes were developed because of the wide range of pond sizes.

Total revenue (TR) was computed for the whole production cycle using the production functions to estimate net fish production for both the first and second 90-day fish culture periods and selling prices of ₱9*/kg and ₱5/kg for Tilapia and carp, respectively. Initial stocking weight was assumed to be 5 g per fish. Profit was derived by subtracting TVC from TR.

Internal rate of return per annum into perpetuity (IRR) was computed for the various pond sizes and systems as follows:

$$IRR = \frac{TR - TVC}{TFC + \frac{1}{2} TVC} \times 1.5 \qquad \ldots\ldots 1)$$

*₱7.40 = US$1.00.

Table 2. Budget for a 10,000 m^2 excavated pond with pump filling and drainage receiving manure from 100 pigs for an 8-month production cycle.[1]

Fixed costs		
a)	Land clearing at ₱3,000/ha	₱ 3,000.00
b)	Dikes[2]	38,360.00
c)	Drain pipe[3]	2,600.00
d)	Water inlet structure	150.00
e)	Storage building[4]	3,200.00
f)	Engineering fee, 6% of a to e	2,840.00
g)	Pump[5]	9,350.00
h)	Buckets[6]	3,920.00
i)	Seine[6]	2,772.00
j)	Wheelbarrow	200.00
		₱ 66,392.00
Variable costs		
k)	Land rent[2]	₱ 1,104.00
l)	Irrigation fee at ₱390/ha/yr	260.00
m)	Fingerlings at ₱0.15 each, 3-5 g each	6,000.00
n)	Labor[8]	555.00
o)	Poison[9]	21.00
p)	Fuel[5]	3,670.00
q)	Maintenance10	2,107.00
r)	Equipment depreciation[11]	2,565.00
		₱ 16,282.00
Revenue		
s)	Tilapia, 3013 kg at ₱9.00/kg	₱ 27,117.00
t)	Carp, 627 kg at ₱5.00/kg	3,135.00
		₱ 30,252.00

Notes:
[1] ₱7.40 = US$1.00; unless noted otherwise, all costs are the same for all pond sizes.
[2] from Table A in the Appendix.
[3] from Table C in the Appendix.
[4] from Table D in the Appendix.
[5] from Table E in the Appendix.
[6] from Table F in the Appendix.
[7] ₱1,656/ha/year based on a typical landlord's share of 30 cavans of rough rice per year, 46 kg/cavan, ₱1.20/kg.
[8] from Table G in the Appendix.
[9] ₱10.60/ha/application based on 0.4 mg/l lethal dosage, assumes water depth = 10 cm and covers ½ of the pond bottom. Gusathion price ₱53/litre.
[10] 5% of dike cost plus 2% of pump cost.
[11] Expected life—pump 8 years, buckets 2 years, seine 4 years, wheelbarrow 8 years.

The "½ TVC" is the average operating capital required. The multiplication by 1.5 was required to express the IRR on an annual basis. The relationship of IRR to pond size was described using equations developed by regression techniques.

Results

A. BIOLOGICAL RELATIONSHIPS

The average weight and manure output per pig is presented in Figure 1. The average wet manure output per pig was 134 kg for the first 90 days and 307 kg for the second

90-day period. Maximum average daily manure output was approximately 4 kg of fresh manure or 1.1 kg dry matter per pig. The average composition of the manure was 71% moisture, 11-15% crude protein (Kjeldahl nitrogen x 6.25) and 13-15% ether extract.

Net yield of harvestable *S. niloticus* as a function of manure input using 8,500 Tilapia/ha is shown in Figure 2. The manure levels were determined by multiplying the number of pigs by 0.134 MT and 0.307 MT for the first and second 90-day periods, respectively. A parabola was fitted to the data. The equation is:

$$Y = -364.86 + 150.46X - 3.48X^2 \qquad \ldots\ldots 2)$$

where Y = net yield/ha of Tilapia in 90 days and X = fresh manure input/ha/90 days expressed in tons. The correlation coefficient (r) = 0.8049. Maximum yield of about 1,300 kg/ha/90 days was attained with an input of approximately 20 MT of fresh manure/ha/90 days.

Figure 3 shows the response of 17,000 Tilapia/ha to manure input. The equation describing the fitted curve is:

$$Y = 25.915 + 132.787X - 2.655X^2 \qquad \ldots\ldots 3)$$

where Y is net Tilapia yield and X is manure input. The correlation coefficient (r) = 0.8060. Maximum yield with 17,000 Tilapia/ha occurred when about 25 MT of fresh manure was added to the ponds. Twenty five metric tons of fresh manure in 90 days is equivalent to the manure output from 83 pigs during the second 90-day period.

The downward slope of the curves at high manure levels indicates that excessive manuring depresses *S. niloticus* production. Also, it is readily apparent that 17,000 Tilapia/ha produces higher yields than 8,500 Tilapia/ha.

The carp data were more difficult to analyze because varying numbers and sizes were stocked due to a carp fingerling shortage. The equation

$$\log_e Y = 3.8209 + 0.4736 \log_e M + 0.1771 \log_e B \qquad \ldots\ldots 4)$$

where

Y = net carp yield in kg/ha for 90 days
M = fresh manure in MT/ha/90 days, and
B = carp biomass in kg/ha

produces acceptable estimates. The correlation coefficient (r) = 0.7811 and the number of data points (n) = 32.

Equations 2 to 4 predict the yield for 90 days only. To estimate the yield for the whole production cycle, yields for both first and second 90-day periods must be computed using the appropriate manure input levels. Maximum Tilapia yields with 17,000 *S. niloticus* for both periods is 2,930 kg/ha attained with 98 pigs/ha. If the carp yield is included, the maximum yield increases to 3,549 kg/ha/180 days at 103 pigs/ha. However, because Tilapia and carp have different selling prices, maximum revenue is attained at 100 pigs/ha.

B. ECONOMIC ANALYSES

The first analysis was the comparison of the increased profits generated by using 17,000 Tilapia versus the doubling of fingerling costs. At all points along the curves (Figures 2 & 3), it is more profitable to use the higher stocking rate. The higher stocking rate is used in all of the following analyses.

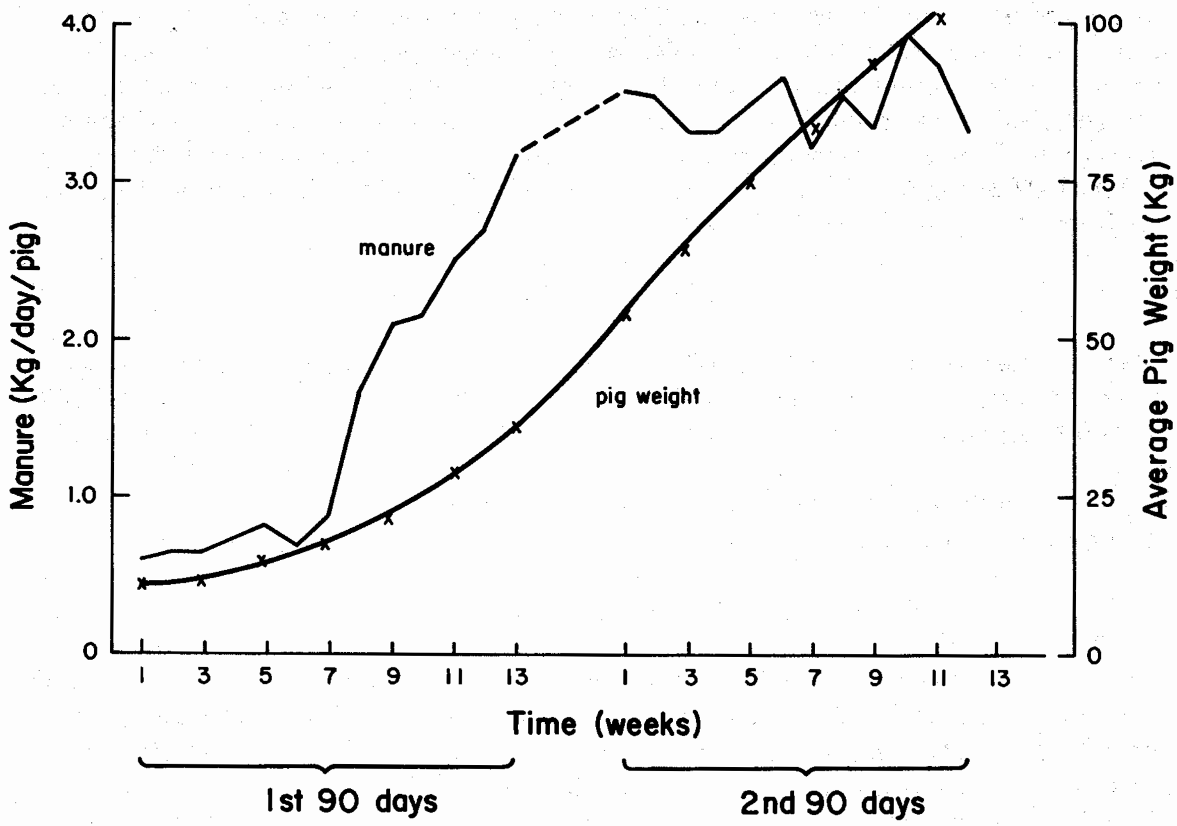

Figure 1. Average daily fresh manure output per pig and average pig size.

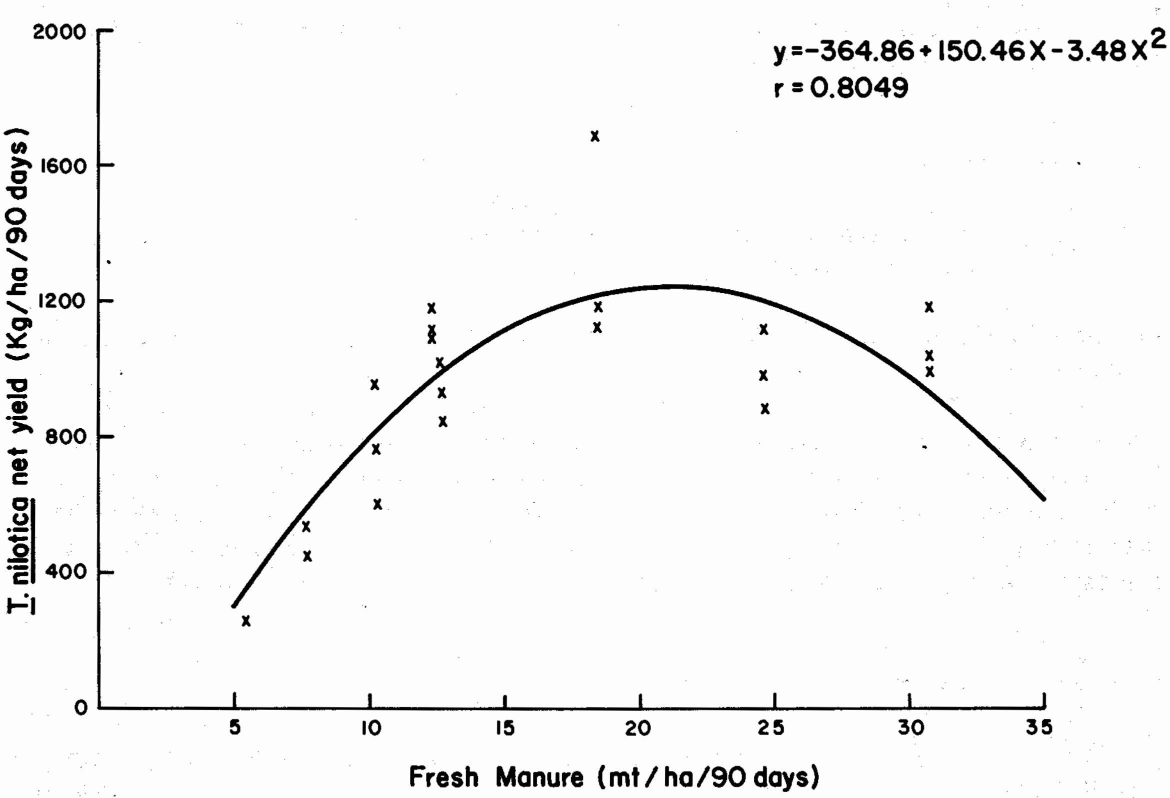

Figure 2. Net yield of *Sarotherodon niloticus* stocked at 8,500 fish/ha for 90-day periods as e function of manure output.

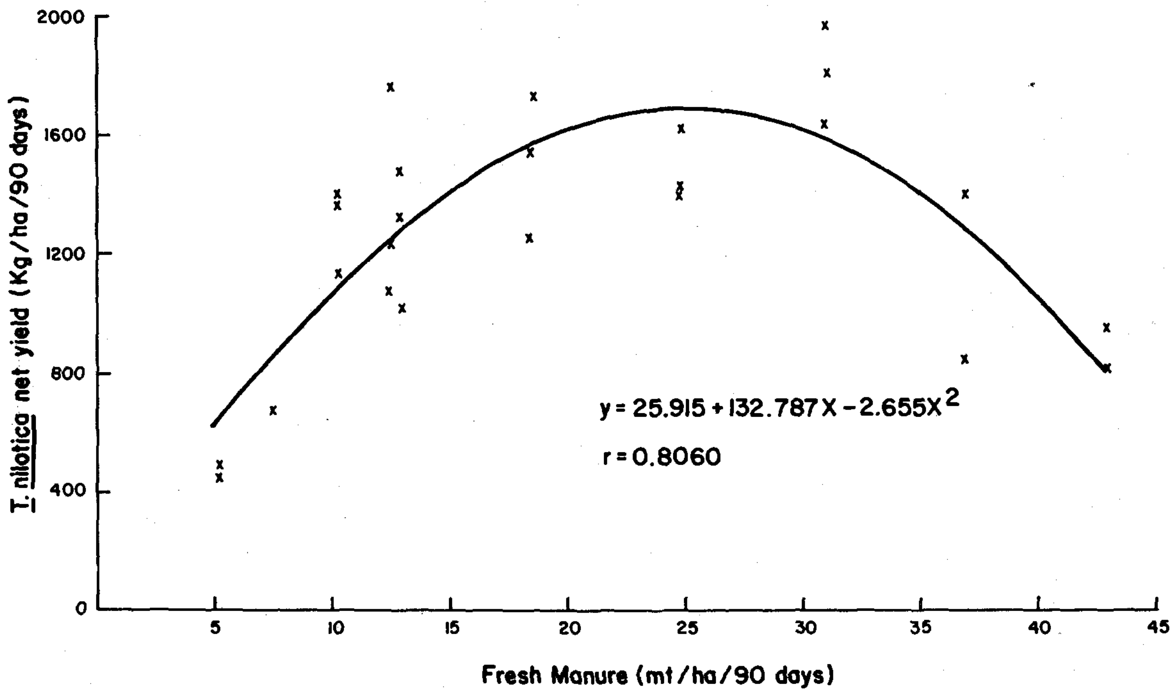

Figure 3. Net yield of *Sarotherodon niloticus* stocked at 17,000 fish/ha for 90 days as a function of manure input.

In the following sections, methods to optimize the number of pigs and pond sizes based on profit and internal rate of return into perpetuity are presented using Philippine data. The optima are by no means inviolate. They are highly dependent on cost estimates. In other countries, and even at other locations in the Philippines, costs can vary. Also, the optima are based on stocking 20,000 fish per hectare. Higher or lower levels may be preferred in certain cases so the optima may shift.

The equations describing the cost data are presented in Table 3. The "fit" of the combined curves, low and high range, to the data was excellent. The TVC curves for both gravity water systems are almost identical as are the TVC curves for the pumped systems. The only major differences are the intercepts. As the slopes are positive, the larger the pond, the greater the TVC and TFC. It is not as readily apparent from the equations that there are very large economies of scale in fish pond construction and operation. For example, the average TFC and TVC for a 100 m^2 excavated pond with gravity water system are ₱22.28/m^2 and ₱3.83/m^2 respectively but the TFC decreases to ₱3.34/m^2 and TVC to ₱1.03/m^2 for a 5 ha pond.

Most of the people who have expressed interest to us in establishing pig-fish systems can be classified into two broad categories. The first are those pig raisers (or potential pig raisers) who have large numbers of pigs but only limited area suitable for fish ponds. The second category are those farmers who have adequate land but limited number of pigs.

In the case of the piggery operator with a large amount of manure relative to pond size, the operator will add manure at that rate which will maximize revenue per unit area. Maximum TR/ha for the entire production cycle is attained with 100 pigs/ha. Manure in excess of this level will decrease TR/ha so any excess manure will have to be disposed by alternative means.

The relationship of profit to pond size under the conditions of limited pond area are illustrated in Figure 4. Profit (TR – TVC) increases as pond size increases. Also, as the pond

Table 3. Equations for the computation of total fixed cost (TFC) and total variable cost (TVC) in Philippine pesos for an 8-month production cycle for various pond sizes. ₱7.40 = US$1.00.

Pond Type	Water System	Applicable Range m^2	Equation Number	Equation[1]
Excavated	Gravity	100 - 7,575	1	$\log_e TFC = 4.4102 + 0.7163 \log_e X$
		7576 - 50,000	2	$TFC = 28497 + 2.7657\ X$
		100 - 1,500	3	$\log_e TVC = 2.7471 + 0.6952 \log_e X$
		1501 - 50,000	4	$TVC = 989 + 1.0145\ X$
Excavated	Pump	500 - 8,750	5	$\log_e TFC = 6.3324 + 0.5167 \log_e X$
		8751 - 50,000	6	$TFC = 28908 + 3.6938\ X$
		500 - 1,200	7	$\log_e TVC = 3.2777 + 0.6866 \log_e X$
		1201 - 50,000	8	$TVC = 1680 + 1.4592\ X$
Levee	Gravity	100 - 1,525	9	$\log_e TFC = 5.4568 + 0.6497 \log_e X$
		1526 - 50,000	10	$\log_e TFC = 6.2819 + 0.5371 \log_e X$
		100 - 2,600	11	$\log_e TVC = 3.0293 + 0.6856 \log_e X$
		2601 - 50,000	12	$TVC = 1899 + 1.013\ X$
Levee	Pump	500 - 8,725	13	$\log_e TFC = 6.9539 + 0.4793 \log_e X$
		8726 - 50,000	14	$TFC = 49213 + 3.6533\ X$
		500 - 1,450	15	$\log_e TVC = 3.7882 + 0.6315 \log_e X$
		1451 - 50,000	16	$TVC = 2255 + 1.4679\ X$

[1] X = size of pond in m^2, $r > 0.99$.

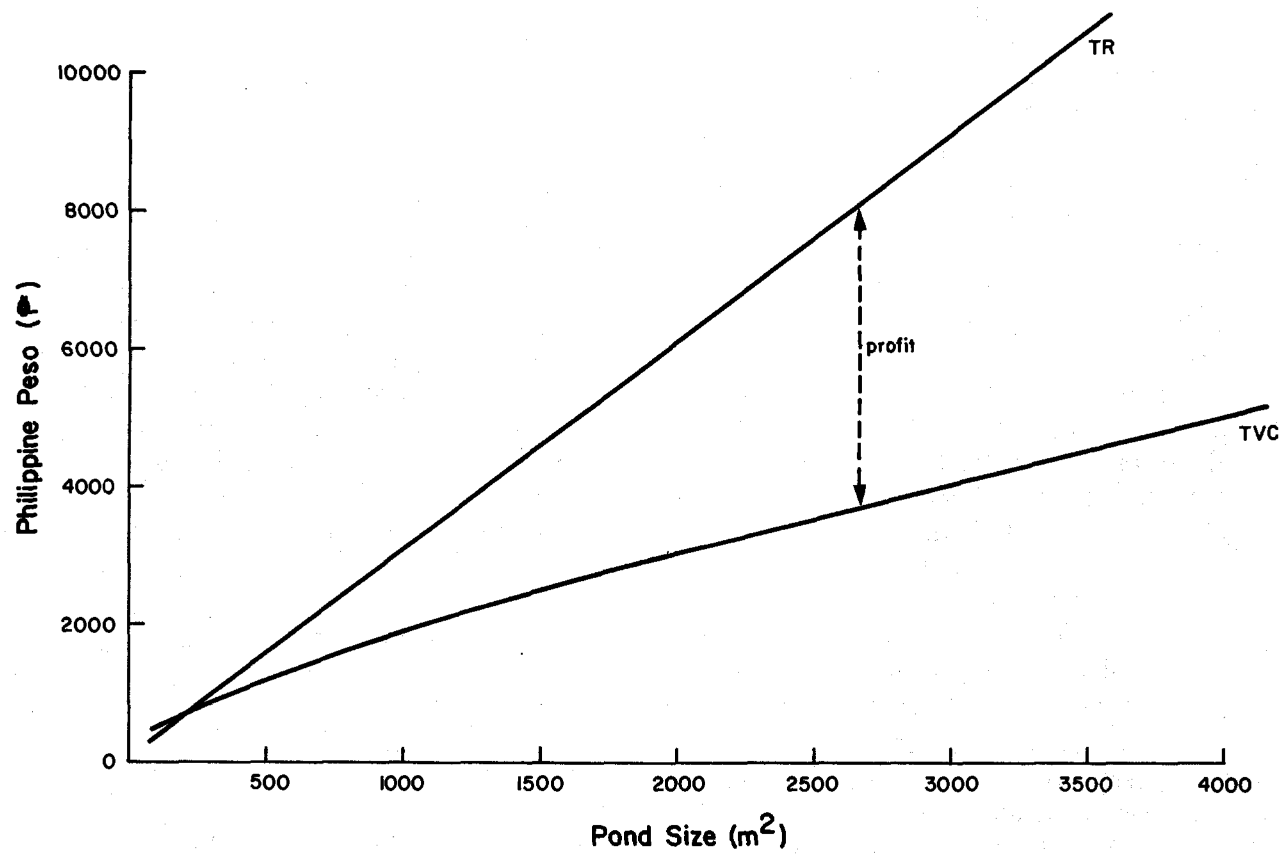

Figure 4. Total revenue (TR) and total variable cost (TVC) for excavated ponds with gravity water systems receiving the manure from 100 pigs/ha. Time period = 8 months. ₱7.40 = US$1.00.

size increases, profit per unit area increases. For example, profit/m^2 is approximately ₱1.20 for a 1,000 m^2 pond and ₱1.76/m^2 for a 3,500 m^2 pond. However, profit per unit area rapidly stabilizes after 3 ha. The upper limits on pond size will depend on manageability, topography and market limitations.

When the number of pigs are limited, a different situation occurs. Figure 5 illustrates this situation. If a farmer has 10 pigs, he can produce 355 kg of fish from 1,000 m^2 or 536 kg from 2,000 m^2 (equations 3 and 4). But the larger pond costs more to build and operate. Maximum profit occurs at the point where the distance between the TVC and TR curves is greatest. The points of maximum profit were computed by an iterative process. For 10 pigs with an excavated pond and gravity water system, the point is a pond size of 1,887 m^2 and for 20 pigs, 3,774 m^2. Both points of maximum profit are equivalent to a rate of 53 pigs/ha. Because TVC is linear over most of its range and the TR curve only flattens but does not change its basic orientation vis-a-vis the TVC line, the optimum for profit maximization will be 53 pigs/ha for any limited number of pigs given the same pond type and water system. However, for very small ponds TVC is not linear so the optima will shift slightly. Figure 6 shows the relationship of the number of pigs to pond size when profit is maximized. The curves for both pumped water system are essentially the same. Further, the gravity water systems also have essentially the same curves. The divergence of the curves in the lower range is caused by the TVCs becoming curvilinear. In general, for limited number of pigs, 53 pigs/ha will maximize profit with gravity water systems, while 67 pigs/ha are required for pumped water system.

The preceding optima were determined using profit maximization as the decision criterion. However, if capital is a limiting factor, internal rate of return may be a better decision criterion. For the farmer with large numbers of pigs and/or limited pond area, 100 pigs/ha will maximize IRR. With limited number of pigs 70 pigs/ha to 90 pigs/ha

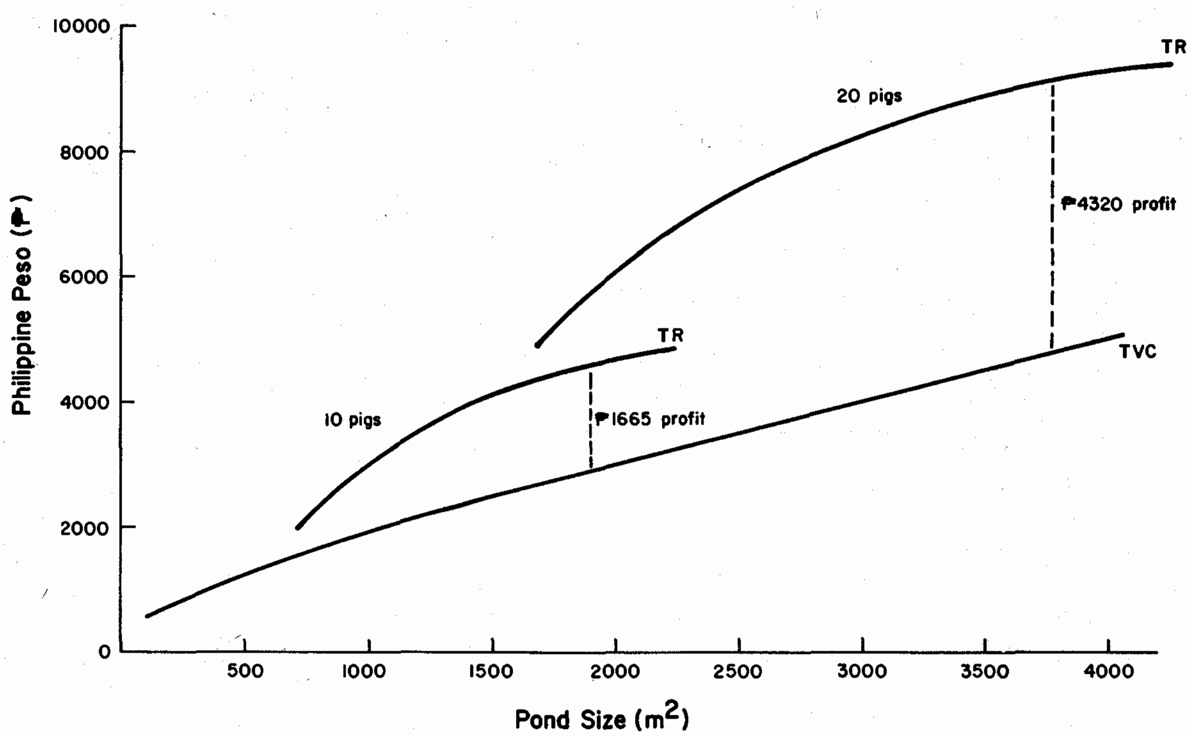

Figure 5. Total revenue (TR) and total variable cost (TVC) for excavated ponds with gravity water systems receiving the manure from 10 or 20 pigs. Time period = 8 months. ₱7.40 = US$1.00.

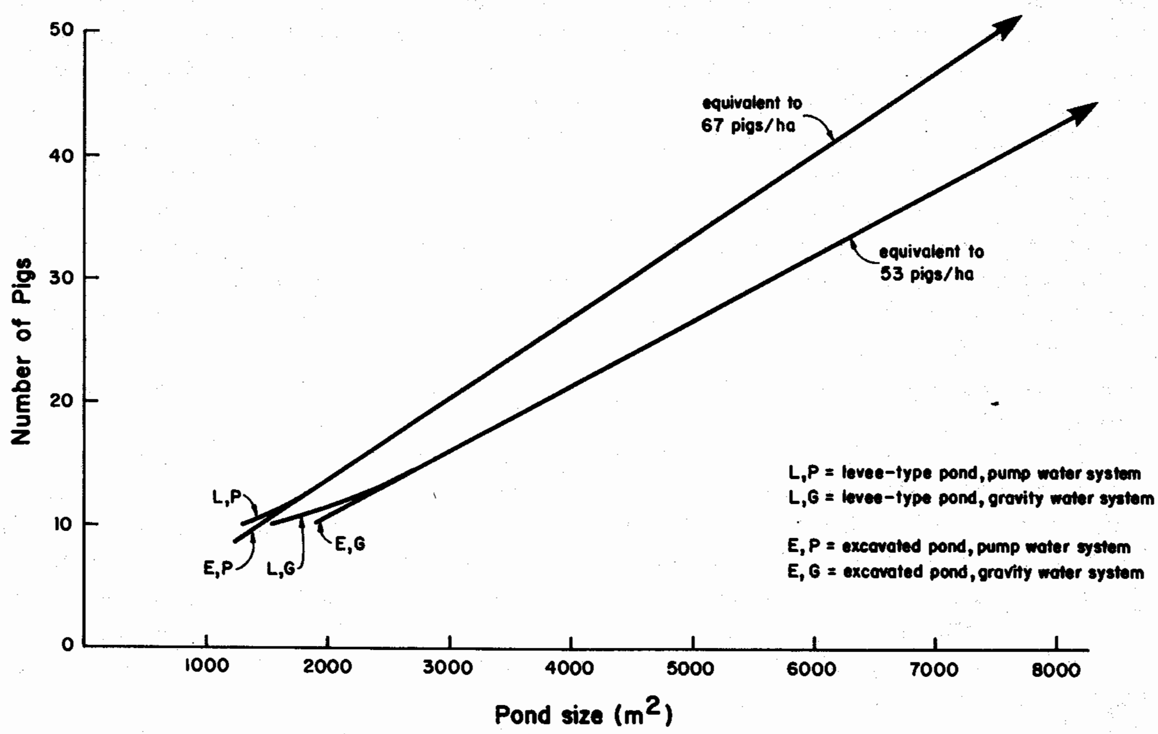

Figure 6. Relationship of number of pigs to pond size when profit is maximized.

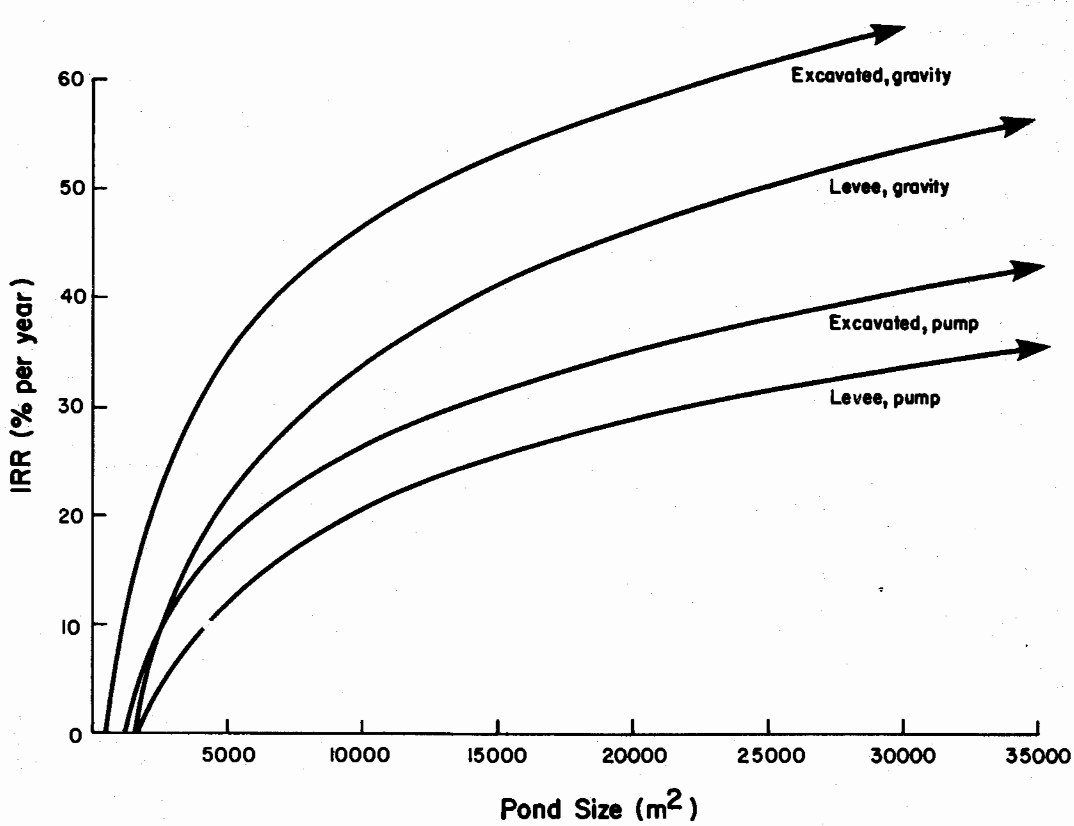

Figure 7. Internal rate of return into perpetuity as a function of pond size for four pond type/water system combinations receiving manure from 80 pigs/ha.

Table 4. Equations relating internal rate of return (IRR) to pond size when manure is added at the rate of 100 pigs/ha.

Pond Type	Water System	Equation[1]	Correlation Coefficient
Excavated	Gravity	$Y = -99.06 + 16.28 \log_e X$	0.9932
Excavated	Pump	$Y = -86.19 + 12.41 \log_e X$	0.9982
Levee	Gravity	$Y = -107.23 + 16.02 \log_e X$	0.9780
Levee	Pump	$Y = -80.79 + 11.35 \log_e X$	0.9879

[1]X = size of ponds in m^2

Table 5. Equations relating internal rate of return (IRR) to pond size when manure is added at the rate of 80 pigs/ha.

Pond Type	Water System	Equation[1]	Correlation Coefficient
Excavated	Gravity	$IRR = -112 + 17.20 \log_e X$	0.9950
Excavated	Pump	$IRR = -93 + 12.99 \log_e X$	0.9990
Levee	Gravity	$IRR = -133 + 18.147 \log_e X$	0.9922
Levee	Pump	$IRR = -92 + 12.24 \log_e X$	0.9983

[1]X = size of ponds in m^2

maximizes IRR. However, the differences between the IRRs obtained using 90 pigs/ha and 70 pigs/ha at any given pond size are negligible. Therefore, as a general rule, with limited number of pigs, 80 ± 10 pigs/ha will maximize IRR.

The magnitude of the IRR is dependent not only on the manure input but also on the pond type, water system, and pond size. Tables 4 and 5 present equations which describe the expected IRR for the different pond systems as a function of pond size when manure is added from 100 pigs/ha and 80 pigs/ha respectively. Figure 7 shows the IRRs which can be expected when adding the manure from 80 pigs/ha.

Gravity water systems have a higher IRR than pumped water systems because gravity systems are less expensive to operate. Likewise, excavated ponds yield a higher IRR than levee-type ponds because excavated ponds are cheaper to build. Absolute breakeven point (TR = TVC) varies between 700 to 1,800 m^2 when using 80 pigs/ha. However, banks in the Philippines are now giving 15-18% on certificates of deposit so ponds must be at least 2,100 m^2 (for excavated ponds with gravity water systems) to 10,000 m^2 (for levee-type ponds with pump water systems) in order to yield an equivalent return.

Conclusions

The relationships of pig manure to *S. niloticus* net yields can be explained by equations of the form $Y = a + bX + cX^2$ where Y = fish yield and X = fresh manure input. From these equations the following can be concluded:

A) Maximum Tilapia net yield of approximately 1,700 kg/ha/90 days is attained when pig manure is added at the rate of 25 mt/ha/90 days.

B) Stocking 20,000 fish/ha (85% Tilapia, 15% carp) leads to higher production than stocking 10,000 fish/ha.

Based on prevailing 1980 Philippine prices, the following optimum pig-pond surface area relationships were determined.

A) With large numbers of pigs and/or limited pond area, 100 pigs/ha will maximize total revenue and profit.
B) When the number of pigs is limited, 53 pigs/ha will maximize profit for gravity water systems and 67 pigs/ha will maximize profit for pumped water systems.
C) Internal rate of return is maximized by using 100 pigs/ha for systems with limited pond area and with 80 ± 10 pigs/ha for system with limited pig numbers.

Additionally, the following can also be concluded:

A) It is more profitable to stock 20,000 fish/ha than 10,000 fish/ha.
B) Freshwater fish pond operations are greatly influenced by economies of scale such that new ponds below 2,000 m^2 will not yield as high a return as bank deposits.

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APPENDIX TABLES

Table A. Dike specifications, volumes and costs for an excavated pond.

Area m^2	Depth[1] (m)	Crown (m)	Height[2] (m)	Core (m x m)	X-section[3] m^2	Perimeter[4] (m)	Volume m^3	Cost[5] (₱)
100	1.5	1	0.5	.5 x .5	1.25	46	58	580
500	1.75	1.5	0.94	.5 x .5	3.43	101	346	3,460
1,000	2	2	1.16	.5 x .5	5.25	142	746	7,460
2,500	2	2	1.37	.5 x .5	6.74	220	1484	14,840
5,000	2	2	1.49	.75 x .75	7.98	308	2458	24,580
7,500	2	2	1.56	.75 x .75	8.55	375	3206	32,060
10,000	2	2	1.61	.75 x .75	8.88	432	3832	38,320
20,000	2	2	1.70	.75 x .75	9.74	608	5922	59,220
30,000	2	2	1.75	.75 x .75	10.19	743	7571	75,710
40,000	2	2	1.78	.75 x .75	10.45	857	8956	89,560
50,000	2	2	1.80	.75 x .75	10.64	957	10181	101,810

[1]Top of dike to pond bottom includes 20-25% allowance for shrinkage.

[2]Top of dike of ground surface. Calculated by equating volume of dike to volume of soil excavated from the pond bottom.

[3]Side slope–2:1 (horizontal:vertical). Calculated by equating volume of dike to volume of soil excavated from the pond bottom.

[4]Assumes 2:1 length:width proportion and includes the corners of the dikes. A 3:1 length:width proportion is preferred but based on experience will not be used by most pond operators/owners.

[5]At ₱10/m^3, ₱7.40 = US$1.00.

Table B. Dike specifications, volumes and costs for a levee type pond.

Area (m^2)	Depth[1] (m)	Crown (m)	Core (m x m)	X-section[2] m^2	Perimeter[3] (m)	Volume (m^3)	Cost[4] (₱)
100	1.5	1	.5 x .5	6.25	46	288	2,880
500	1.75	1.5	.5 x .5	9.00	101	909	9,090
1,000	2	1	.5 x .5	12.25	142	1740	17,400
2,500	2	2	.5 x .5	12.25	221	2707	27,070
5,000	2	2	.75 x .75	12.56	208	3868	38,680
7,500	2	2	.75 x .75	12.56	375	4740	47,400
10,000	2	2	.75 x .75	12.56	432	5426	54,260
20,000	2	2	.75 x .75	12.56	608	7636	76,360
30,000	2	2	.75 x .75	12.56	743	9332	93,320
40,000	2	2	.75 x .75	12.56	857	10763	107,630
50,000	2	2	.75 x .75	12.56	957	12016	120,160

[1]Top of dike to pond bottom. Includes 20-25% allowance for shrinkage.

[2]Assumes 2:1 (horizontal:vertical) side slope.

[3]Assumes 2:1 length:width proportion and includes the corners of the dikes. A 3:1 length:width proportion is preferred but will not be used by most pond operators/owners.

[4]At ₱10/m^3, ₱7.40 = US$1.00.

Table C. Drainage pipe requirements.

Area (m^2)	Pipe Size (in)	Length[1] (ft)	Cost[2] (₱)
100	4	30	750.00
500	4	40	961.00
1,000	4	50	1,172.00
2,500	6	50	2,600.00
5,000	6	50	2,600.00
7,500	6	50	2,600.00
10,000	6	50	2,600.00
20,000	8	50	4,750.00
30,000	8	50	4,750.00
40,000	8	50	4,750.00
50,000	8	50	4,750.00

[1]Width of dike plus 2 meters clearance plus 1.5 meter height rounded to nearest 10 feet.
[2]Includes the cost of 1 coupling per 10 ft. of pipe and 1 elbow. ₱7.40 = US$1.00.

Table D. Storage building requirements.

Pond Area (m^2)	Building Size (m x m)	Cost[1] (₱)
100[2]	–	–
500[2]	–	–
1,000[2]	–	–
2,500	2 x 2	1,600.00
5,000	2 x 2	1,600.00
7,500	3 x 2	2,400.00
10,000	4 x 2	3,200.00
20,000	4 x 2.5	4,000.00
30,000	4 x 3	4,800.00
40,000	4 x 3	4,800.00
50,000	5 x 3	6,000.00

[1]₱400/m^2 includes galvanized iron walls and roof and concrete floor, ₱7.40 = US$1.00.
[2]Available storage space at piggery should be sufficient.

Table E. Pump requirements capital costs and operating costs for one complete cycle (8 months).

Area (m^2)	No. of Units	Pump Size[1] (in)	Capacity[2] (gpm)	Engine Size[3] (hp)	Cost (₱)	Fuel Consumption l/hr/unit	Fuel[4] Filling	Cost[5] Draining
100	0	–	–	–	–	–	–	–
500	1	6	500	4	7030	1.5	132	34
1,000	1	6	600	7	7550	2.5	366	92
2,500	1	8	1,300	10	9170	3.7	626	156
5,000	1	8	1,500	12	9350	5.0	1468	366
7,500	1	8	1,500	12	9350	5.0	2202	550
10,000	1	8	1,500	12	9350	5.0	2936	734
20,000	2	8	1,500	12	18700	5.0	5872	1468
30,000	3	8	1,500	12	28050	5.0	8808	2202
40,000	4	8	1,500	12	37400	5.0	11744	2936
50,000	5	8	1,500	12	46750	5.0	14678	3668

[1]Self-priming, single-stage axial flow pumps.
[2]Estimate based on 3 to 4 meter TDH.
[3]4-cycle, air-cooled gasoline engines.
[4]2X volume of pond per 90 day fish culture period because of seepage and evaporation. Gasoline—₱5.00/l, ₱7.40 = US$1.00.
[5]Assumes that pond volume can be decreased by ½ by gravity drainage. Gasoline—₱5.00/l.

Table F. Miscellaneous equipment requirements.

Area (m^2)	Seine Length[1] (m)	Seine Depth[2] (m)	Cost[3] (₱)	No. of Buckets[4]	Costs[5] (₱)
100	11	1.5	288	2	70
500	24	1.5	628	6	210
1,000	34	1.5	889	12	420
2,500	53	1.5	1386	28	980
5,000	75	1.5	1961	56	1960
7,500	92	1.5	2406	84	2940
10,000	106	1.5	2772	112	3920
20,000	150	1.5	3923	224	7840
30,000	184	1.5	4812	336	11760
40,000	212	1.5	5544	448	15680
50,000	237	1.5	6198	560	19600

[1]Width of pond x 1.5.
[2]Greatest depth after partial drawdown x 1.5.
[3]₱21/meter length/meter depth plus ₱10.30 for each additional meter depth, ₱7.40 = US$1.00.
[4]Based on a maximum possible harvest per 90 days of 2800 kg/ha, bucket capacity of 25 kg. 560 buckets for 50,000 m^2 is unrealistic but a comparable holding capability would have to be developed.
[5]At ₱35/bucket.

Table G. Labor requirements for 1 period (8 months).

Area (m^2)	Stocking[1] (man days)	Harvest[2] (man days)	Grass Cutting[3] (man days)	Cost[4] ₱
100	4	8	3	225
500	4	8	6	360
1,000	4	8	9	315
2,500	4	8	14	390
5,000	4	8	19	465
7,500	4	8	23	525
10,000	4	8	27	585
20,000	4	16	38	870
30,000	4	24	46	1110
40,000	4	32	53	1335
50,000	4	40	59	1545

[1]Two men can stock 100 m^2–50,000 m^2 in one day. Minimum hiring unit is for one day.
[2]A minimum of 4 laborers are needed to harvest one pond and they can harvest up to a 1 ha pond in one day, times 2 harvests.
[3]0.5 man day every 2 weeks per 130 meters of dike every 2 weeks based on observation. Does not conform to minimum hiring unit because juveniles can be hired to cut grass for less than one day.
[4]At ₱15/day, ₱7.40 = US$1.00.