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The Feasibility of Small-Scale Hapa Culture of Tilapia *Oreochromis niloticus* as an Additional Income Source for Rice Farmers in Northeast Thailand

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Abstract

In Northeast Thailand, hapa culture of tilapia may provide interesting perspec-tives for rural development. Besides being a suitable method for managing fish produc- tion in village ponds, it may generate additional income for local rice farmers. In the present study, rice farmers raised tilapia *Oreochromis niloticus* in small hapas (water volume 8 m^3) in village ponds. Fish were fed a commercial diet (protein content 35%). Tilapia stocked at an initial weight of 50 g attained a mean specific growth rate of 1.46% of the body weight (BW) per day. Market size was attained after an average rearing time of 85 days. The mean feed conversion ratio was 1.4.

The economic analysis was based on the observed plus four theoretical produc-tion scenarios. Investment costs were about 5% of total operating costs. Fingerling costs (about 25% of total costs) could be considerably reduced when fingerlings were collected from backyard ponds or from the hapas ("wild spawning"). Feed costs amounted to 70% of total costs but could be reduced by optimizing the feeding regime and home-mixing of fish feed. Stocking weight was not an important economic variable but affects the rearing period to reach market size. Shorter rearing periods gave higher daily gross margins, and were preferred by local rice farmers. A rearing period of 100 days may be a suitable compromise between the farmers' preference for short production cycles, the harvest size of the fish and the profitability of the hapa culture.

Large fingerlings (W_0= 50 g), stocked at a density of 14 fish·m^{-3}, may reach a suitable market size of 216 g in 100 days. If smaller fingerlings are stocked, two rearing cycles will be needed to reach market size. In this way, rice farmers may increase their household income by about 20%.

Introduction

In Northeast Thailand, fish yields from village ponds are often disappointing due to poor water quality, the structure of the natural fish populations (few commercially valuable species and many small invaluable species) and the absence of adequate pond management. Communal ponds are typical open-access resources which are exploited by the farmers with cast nets and baited hooks. Their main interest is to maximize individual returns. A shared management for the village ponds is hard to develop due to the size of the ponds and the large number of people involved. However, privatizing fish yields through the introduction of hapa culture may stimulate proper management of the village ponds.

In Northeast Thailand, most villagers are rice farmers. Opportunities for cash investments and labor inputs in activities other than growing rice are limited. Raising fish is, at best, an important side-activity. Small-scale farmers tend to minimize their risks by limiting the capital inputs of their activities. New activities are only tried out if profitability is apparent and capital requirements are low. Farmers are more concerned with the return of their money invested than with increasing yields at higher risks (Middendorp and Verreth 1987). Hapa culture fits very well into this small-scale farmer's attitude. Investment costs are low, leading to favorable returns in spite of the low yields which are normally derived from hapas. Further, the low-carrying capacity of the hapas imposes a more extensive production strategy. To avoid the biomass exceeding the carrying capacity, fish densities are kept low and growth cycles short (about 3 months). Small-scale farmers tend to prefer such short growth cycles because it reduces the risk of hapa damage, theft, etc. In order to reduce the capital requirements for feeding, hapa management is geared towards optimizing feed conversion ratio.

In this study, on-farm trials were conducted to estimate growth and feed conversion of tilapia *Oreochromis niloticus* reared in hapas under local farming conditions of Northeast Thailand. General management guidelines were based on results obtained earlier in pilot experiments (Middendorp and Verreth 1991a).

Growth and feed conversion data are compared with data from cage culture trials, as reported in the Thai literature. An economic analysis of hapa culture of tilapia is presented, using four production scenarios which differed from each other in rearing time, fish density and stocking weight of the fish.

Materials and Methods

Eleven farmers from two villages participated in the trials. Farmers 1-7 lived in Ponebeng Village and farmers 8-11 in Jantung. One farmer had two hapas; the others had one hapa each (Table 1). Fingerlings were bought from the Srisaket Agricultural College and transported to the farmers in plastic bags filled with oxygen (total transport time: 5 hours). Fingerlings were stocked in January 1987. Mean fingerling weight at stocking was 50 g. Hapas measured 3.7 x 1.8 x 1.8 m (water volume 8 m^3) and were constructed of blue nylon mosquito netting (6 strings/cm, mesh opening 1.5 x 1.5 mm) (Middendorp 1988).

A commercial floating catfish pellet (protein content 35%) (Charoen Pokhpand Co.) was fed. Farmers were instructed to feed three times per day until satiation. Rearing time (t) was defined as the number of days the fish had been fed: 86 days in Ponebeng and 84 days in Jantung. Water temperatures in the afternoon ranged between 25 and 28 °C; pH varied from 6 to 7.

Fish were batch-weighed and counted at stocking and at harvest, and mean initial (W_0) and mean final weight (W_t) were calculated. During the first days after stocking, some mortality occurred. These mortalities were probably caused by transport and handling

Table 1. Production data of small-scale hapa culture of tilapia *O. niloticus* obtained in on-farm trials in Northeast Thailand. The study involved 11 farmers. Farmer no. 7 had two hapas. Data in parenthesis refer to standard deviations (n-1 basis).

	Ponebeng village	Jantung village
No. of hapas	8	4
Rearing time (days)	86	84
Fish stocked		
mean no. $hapa^{-1}$	125	159
mean weight W_0 (g)	50	50
Fish harvested		
mean no. $hapa^{-1}$	86 (± 7.6)	57 (± 13.6)
mean weight W_t(g)	194 (± 39.6)	152 (± 2.1)
yield·$hapa^{-1}$ (kg)	16.6 (± 4.2)	8.4 (± 1.9)
Overall survival rate (%)	68.4	36.1
Growth (g·day^{-1})	1.67 (± 0.46)	1.21 (± 0.03)
SGR (%BW·day^{-1})	1.56 (± 0.24)	1.28 (± 0.09)

at stocking and were not considered to have influenced the experimental densities during the growth period. In accordance with observations and procedures followed in earlier pilot experiments (Middendorp and Verreth 1991a), final fish densities were considered as the experimental densities. To correct for the incurred mortality, total stocking weight was adjusted by multiplying W_0 with the (*a posteriori* determined) experimental fish density (N) ($TW_0' = N \cdot W_0$). Individual growth was expressed in $g \cdot day^{-1}$. Specific growth rate (SGR) per hapa was calculated as:

$$((\ln W_t - \ln W_0)/t) \cdot 100 \ (\%BW \cdot day^{-1})$$

Feed conversion ratio (FCR) was computed as the total amount of feed administered, divided by the total weight at harvest (TW_t) minus the adjusted total weight at stocking (TW_0'). The average feeding level (R) was calculated as FCR·SGR (% $BW \cdot day^{-1}$). Hapa production (HP) was defined as the total yield minus the adjusted total stocking weight.

Means and coefficients of variation (CV) were computed. Differences in SGR between villages were tested (t-test, $P \leq 0.05$).

Economic Analysis

Several production scenarios were compared. The results and conditions of the present study (W_0 = 50 g, rearing time t = 85 days, three feedings *ad libitum* per day) were used to estimate production parameters for four different hypothetical production scenarios (Table 2). These production parameters were subsequently used for an economic comparison of the scenarios. For each of the scenarios, the final weight at harvest was calculated by subdividing the rearing period in intervals of 10 days, for each of which the final weight was calculated from the corresponding initial weight and SGR. In earlier trials (Middendorp and Verreth 1991a), a curvilinear relation between SGR and initial weight was assessed according to the equation: $\ln(SGR) = a \cdot \ln(W_0) + b$. Assuming the same regression slope a (= -0.4055) as found by Middendorp and Verreth (1991a), the appropriate intercept b was derived by iteration, using the results of the present study (t=85 days, W_t = 182 g), yielding a b-value of 2.25. Fish density was estimated from the calculated final

Table 2. Economic analysis of small-scale tilapia *O. niloticus* production in hapas in Northeast Thailand. Four hypothetical production scenarios are compared with the observed data from the village trials. Results of scenarios I, II, III and IV are estimated indirectly from the present study (for explanation see text). All parameters are expressed per hapa and per production cycle.

Scenario	Observed	I	II	III	IV
Production parameters					
stocking weight W_0 (g)	50	50	50	30	30
harvest weight W_t (g)	182	182	216	166	210
rearing time t (days)	85	85	100	100	120
fish density (No.$\cdot$hapa^{-1})	71	137	116	151	119
yield Y (kg$\cdot$hapa^{-1})	12.9	25	25	25	25
net hapa production HP (kg)	9.4	18.1	19.2	20.5	21.4
Economic parameters					
1. *Costs*					
fingerlings (20 B$\cdot$kg^{-1})	71.0	137	116	91	71
mortality (5%)	4	7	6	5	4
feed costs (B)	160	309	327	349	365
fixed costs: depreciation+interest (B)	12	12	14	14	17
Subtotal	246	465	463	458	457
2. *Benefits*					
gross sales (B)	323	625	625	625	625
3. *Profitability*					
return on feed costs (B)	75	144	153	163	171
return on feed costs (%)	47	47	47	47	47
total gross margin (B)	77	160	162	167	168
daily gross margin (B)	0.90	1.88	1.62	1.67	1.40
benefit/cost ratio	0.31	0.34	0.35	0.36	0.37

weight and the empirically determined carrying capacity of 25 kg per hapa (Middendorp and Verreth 1991a) as: $N = 25/W_t$. Net hapa production (HP) was defined as total yield minus the adjusted total weight at stocking (Yield - $(W_0 \cdot N) = (W_t - W_0 \cdot N)$.

The effect of fish density was tested by comparing scenario I with results of the present study. Scenario I differed only in fish density from the conditions in the village trial, using an initial weight of 50 g and a rearing period of 85 days. The three other scenarios were used to test the effect of longer rearing periods and/or smaller fingerling size. In scenario II, the same conditions as in scenario I were used, but rearing period was extended to 100 days. The effect of stocking smaller fingerlings was examined in scenarios

III (W_0 = 30 g, t = 100 days) and IV (W_0 = 30 g, t = 120 days), where the rearing period was further extended to 120 days to obtain a similar final weight as in scenario II.

Costs included fingerling costs (taking into account an initial mortality of 5%), feed costs and depreciation of investments. The cost of fingerlings was set at 20 B·kg^{-1}, i.e., the common market price for live fish in Northeast Thailand. Feeding costs were calculated as FCR·feed price (B·kg^{-1} fish produced). Total feed costs were calculated as hapa Yield·feeding costs (B·hapa^{-1}). FCR was fixed at the mean value observed in this study (FCR = 1.42). At the time of the study (1987), the price of pelleted feeds was B12.0·kg^{-1} (US$1 = B25). Depreciation costs of the initial investments referred to the construction costs of a hapa. Construction of a hapa cost B130, and included only materials. The bamboo needed to construct frames and float were considered to be free of charge since the farmers collected it from nature. Farmers' labor to construct the hapas was excluded from the construction cost. The life span of a nylon hapa was estimated at three years. Depreciation was calculated on a straight-line basis, and interest on capital was estimated at 6%. Over a three-year period, depreciation amounted to B43 per year, and interests demanded B8 per year, giving a total depreciation cost per year of B51. For each of the scenarios, these fixed costs per year were further reduced to the appropriate rearing period on a straight-line basis.

Economic parameters included gross value, return on feed costs, total and daily gross margin, and the benefit/cost ratio. Gross sale value was calculated as a total hapa yield (kg) times market price (B25·kg^{-1}). Return on feed costs was defined as gross sale minus total feed costs. Total gross margin was defined as gross sale minus total costs. Daily gross margin (B·day^{-1}) is total gross margin divided by the number of rearing days (t). The benefit/cost ratio was calculated as total gross margin divided by total costs.

Results

Depending upon fish density, yields ranged from 6.4 kg to 24.5 kg·hapa^{-1} in 84-86 days. In total, 166.5 kg of tilapia were harvested giving an overall mean individual weight at harvest (W_{85}) of 182 g. The overall mean (12 hapas) SGR was 1.46% BW·day^{-1} (coefficient of variation (CV) = 16%). SGRs in Ponebeng (8 hapas) and Jantung (4 hapas) were not significantly different (Table 1).

FCR ranged between 0.88 and 1.82 (mean FCR = 1.42; CV = 24%; 5 hapas) (Table 3). Feeding rates (R) ranged from 1.69 to 2.58% (mean R = 2.34%; CV = 16%; 5 hapas) (Table 3).

The economic parameters calculated from the village trials in the present study (Table 2) were: gross sale value B323; return on feed costs B75; total gross margin B77; daily gross margin B0.90 per day; and benefit/cost ratio 31%.

Table 3. Feed conversion ratio and daily feeding rate of tilapia *O. niloticus*, raised in hapas and fed with a commercial diet containing 35% crude protein (n = 5 hapas).

Farmer (no.)	Feed conversion ratio	Feeding rate (R)
3	1.82	2.57
5 (two hapas)	1.45	2.42
6	1.49	2.58
7	0.88	1.69

In all hypothetical production scenarios, total yield per hapa was set at the same level as the carrying capacity, i.e., 25 kg. Consequently, in all scenarios the gross sale value equalled B625. In the same way, return on feed costs was similar for all scenarios (47%) since both hapa yield and FCR were fixed input variables in the analysis. Total gross margin per hapa varied from B160 for scenario I to B168 for scenario IV. Daily gross margins varied between B1.40$\cdot$hapa$^{-1}\cdot$day^{-1} (scenario IV) and B1.88$\cdot$hapa^{-1}day^{-1} (scenario I). Benefit/cost ratios increased slightly with rearing time and varied from 34% (t = 85 days, scenario I) to 37% (t = 120 days, scenario IV).

Discussion

Survival rates were calculated from the number of fingerlings sent in plastic bags, and included transport mortality. It was assumed that total mortality was mainly caused by transport since majority of the mortalities were observed during the first days after stocking. In earlier experiments, mortality due to handling was only 5% or less (Middendorp and Verreth 1991a). In later transports, mortalities were reduced by using a sedative (benzocain 25 ppm) and by tying the bottom corners of the plastic bags with rubber bands to prevent the fish from getting stuck. These observations gave a sound basis to the procedure applied in the present study to estimate fish density N and the 5% mortality loss assumed in the hypothetical production scenarios.

In the present study, SGRs were slightly higher than those assessed by Middendorp and Verreth (1991a). This difference may be explained by different feeding levels. Fish were fed twice per day in the earlier study (mean R = 1.68%), against three times per day in this study (mean R = 2.34%). The FCRs were comparable to those obtained by Middendorp and Verreth (1991a) (1.43 vs. 1.42 in the present study). Tilapia is known to graze cage surfaces efficiently (Edwards 1980 in Schroeder 1983). Grazing of the aufwuchs on the inside of the hapa may partly explain the favorable FCR.

Literature data on Thai cage culture are shown in Table 4. At the same dietary protein level, both SGR and FCR improved with lower stocking density. This supports the production strategy of reducing feed costs by minimizing FCR at low fish densities. Best results were obtained by Duangsawasdi et al. (1986) and are comparable to those of the present study.

Economic Analysis

In Northeast Thailand, the market price of fish is rather uniform. In 1987, tilapia was sold for approximately B25 per kg live fish, and B17 per kg dead fish. Fish stocked in hapas weighed 50 g, a size considered as "almost-for-consumption" and sold for b20 per

Table 4. Cage culture of *O. niloticus* in Thailand. Data adapted from Thai literature. Mean fish weight at stocking (W_0), stocking density (SD, fish·m^{-3}), rearing time (days), daily feeding rate (R, %BW) dietary protein, specific growth rate (SGR) and food conversion ratio (FCR).

W_0 (g)	SD (No.·m^{-3})	t (days)	R (%)	CP (%)	SGR (%BW·d^{-1})	FCR	Source
22	200	210	3	24	0.97	3.20	Suchiduangsanan (1971)
24	400	210	3	24	0.68	4.13	Suchiduangsanan (1971)
53	33	213	5	10	0.66	-	Taowrana and Suwannaphong (1977)
12	47	175	*ad lib*	16.5	1.34	2.63	Jodhkiri et al. (1984)
7	100	70	4	35	2.03	2.02	Jarimopas and Kumnane (1985)
26	100	112	4	35	1.44	2.02	Jarimopas and Kumnane (1985)
21	50	162	2	21.5	1.44	-	Hiranwat et al. (1985)
4	35	168	2	35	2.54	1.37	Duangsawasdi et al. (1986)

kg. Prices are highest in the dry season, and lowest around rice harvesting time when the market is glutted with snakehead and catfish from the fields. Sound production planning may therefore contribute considerably to the returns of hapa culture.

Feeding costs were B17.0 per kg fish produced, leaving a rough profit margin of about B8 per kg of fish production. Direct feed costs may be further reduced by optimizing the feeding regime and by using locally available feedstuffs (Middendorp and Verreth 1991b).

Four production scenarios were compared (Table 2). Feed costs were the highest variable costs and varied from about 65% of the total costs in scenario I to about 70% in scenarios II, III and IV. Fingerling costs were about half as high, making them the next important variable cost item. Mortality losses were estimated at 5% of the total fingerling costs. Investment costs (depreciation plus interest) were low and never rose above 5% of the total costs. Labor costs were not included since feeding was mostly done by the farmer's family. The cost for transporting fingerlings was supposed to be included in the fingerling price.

When less than the optimum number of fingerlings were stocked (as in the village trials compared to scenario I), total costs were reduced accordingly. However, also the total hapa yield decreased and, consequently, the benefit/cost ratio remained very similar. Lower operating costs are directly reflected in lower profits.

Total gross margins and benefit/cost ratios were similar in all four production scenarios. When similar stocking weights were used (such as in scenarios I and II, or in III and IV), the total gross margin and benefit/cost ratio increased only slightly when the rearing time was extended by 15-20 days. Daily gross margin, however, increased markedly with shorter rearing times.

Stocking of small fingerlings combined with short rearing periods may lead to final fish weights below market size (e.g., as in scenario III compared to scenario II). From a marketing point of view, tilapia production should be split over two rearing cycles when smaller fish are stocked.

In case of insufficient sales, the remaining fish can be kept at a lower density and will continue to grow. It is expected that both the return on total costs and the daily gross margin will not be affected much. Such a situation may occur when farmers sell their fish directly to consumers.

In scenario II (14.5 fish.m^{-3}; W_0=50 g), fish reached an estimated mean harvest weight of 216 g in 100 days, which is close to market size. This scenario is therefore recommended. Scenario IV, where smaller (30-g) fingerlings were stocked but rearing time prolonged to 120 days, resulted in a similar final weight, a similar total gross margin and benefit/cost ratio. Nevertheless, scenario II is recommended because the farmer generates a profit in a shorter time than in scenario IV.

Social Relevance and Perspectives for Future Development

In the village trials, the observed gross margin per hapa averaged B77. This was equivalent to a farmgate price of about 35 kg of paddy.

A household of 6-8 persons in the Kho Wang area had a gross annual income of B20,000-30,000 (Kho Wang Rural Resources Formation Project, unpubl. data). In the village trials, the monthly gross margin per hapa was B27. In scenario II, the monthly gross margin per hapa would be B49. This may seem a negligible amount of money, but for a local family, three units of two hapas each may add 12-18% to the monthly household income.

Shortage of fish seed to stock the hapas is not likely. Tilapia breed in the hapas, and fry are collected by the farmers as a welcome by-product. Further, so-called "stunted" tilapia fingerlings may be obtained by farmers from their backyard ponds (200-400 m^2). These fingerlings may easily weigh 50 g or more. Fingerling costs (about 25% of total costs) can be considerably reduced when fingerlings are collected this way. In scenario II, collecting fingerlings instead of buying them would increase total gross margin to B284 per hapa per 100 days. Three units of two hapas each would then increase the household income by 20-31% per month.

Further, hapa culture can be integrated with rice/fish production systems. When the ricefields dry out, many small fish are collected that can be used for stocking the hapas: common carp, tilapia, gourami *Trichogaster pectoralis* and catfish *Clarias* spp.

In intensive cage and hapa farming, the limiting conditions (e.g., bacterial waste removal, oxygen concentration) of the water body should be considered. Therefore, the number of hapas and/or the quantity of fish produced in small-scale hapa culture will be limited by the carrying capacity of the village ponds in which the hapas are suspended.

Under the socioeconomic conditions of Northeast Thailand, it is expected that farmers with access to land will prefer rice cultivation above a full-time occupation in fish culture. Only young, landless farmers may be interested in full-time hapa farming. Therefore, extension agencies should try and introduce this system mainly as an activity which may generate additional income for rice farmers. Small-scale credit, such as already available to registered producers' groups, may help in developing hapa culture. Extension support that conveys self-confidence to farmers and limits their technical risks (without taking responsibilities from the farmers) may be very important, because common knowledge of fish farming is limited.

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