

Status of Integrated Agriculture-Aquaculture (IAA) Systems in Northeast Thailand: Nong Khai Province

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ABSTRACT

In 2007, farm surveys and interviews were conducted in Muang District, Nong Khai Province, Thailand, aimed at finding out the current management practices of small-scale IAA-systems. Thirty-three farms consisting of 66 fish ponds were selected for data collection. Results indicated that the IAA-systems in this area involve smallholding farms which are based on locally available pond inputs. Farm areas range from 1.6 to 3.2 ha, with 2 to 5 ponds per farm. The average area of each pond is 0.32 ha. The water supply for fish farms mainly comes from irrigated water from the Mekong River, as well as from reservoirs and rain. The major groups of fish cultured in these systems are Nile tilapia, Thai silver barb and carps, such as Chinese and Indian major carps. Layer chicken is the main livestock integrated with fish culture. Water from fish ponds are often used for crops.

Key Word: integrated aquaculture, farming system, sustainable aquaculture, fish culture

INTRODUCTION

Most of the northeastern region (80%) is without reliable irrigation from large reservoirs (Khon Kaen University /Ford Foundation Cropping Systems Project, 1982). In the risk prone, resource poor rain fed ecosystems of Northeast Thailand, efforts towards increased agricultural productivity through high-external inputs has been found to be unsustainable both in ecological and financial terms (Setboonsarng, 1996). Farmers use small on-farm ponds and community water resources for supplementary irrigation and catching fish (Little *et al.*, 1996).

Aquaculture is a significant socio-economic activity, especially for rural communities, contributing to livelihoods, food security and poverty alleviation (Edwards *et al.*, 2002). At present, aquaculture is regarded worldwide as one of the fastest growing food-producing sub-sectors, demonstrated by a continuous increase in total production throughout the last decade or more (Ahmed and Lorica, 2002). However, a tightening world grain supply may curtail growth, as fish production requires large inputs of feed. Farmed fish yield about 1 kg of meat for every 3 kg of feed (Brown and Kane, 1994). Ninety two percent of the world's aquaculture production comes from

resource-poor countries in Asia (Brundtland, 1987; NACA/FAO, 2000). At present, in most of the low-income food-deficit countries, finfish aquaculture production is based on the culture of low-value herbivorous/omnivorous freshwater in inland rural communities, within semi-intensive or extensive farming systems that use moderate to low levels of production inputs (Ahmed and Lorica, 2002). The majority of farmers in Asia is poor and cannot provide supplementary feed to their ponds (Azim *et al.*, 2004). In China, the majority of the production emanates from fish ponds of about 1 ha in size that is integrated with crop and livestock production (Chen *et al.*, 1995). In both South and Southeast Asia, large and small peri-urban integrated farming systems that use waste products exist. Fish farms draw on human and animal excreta; rice, vegetables, and fruit trees are irrigated with wastewater; and some feed for livestock and poultry is derived from aquatic plants grown in wastewater (Ghosh, 1990). Integrated aquaculture can be defined within the general definition of integrated farming on the basis of diversification of agriculture towards linkages between sub-systems (Edwards, 1998). The purposes of integration on and between farms comprise of increased diversification, intensification, improved natural resource efficiency, increased productivity and increased sustainability (Lightfoot *et al.*, 1993; Devendra, 1997; ICLARM, 2000). The importance of integrated agriculture-aquaculture (IAA) systems lies with nutrient linkages between pond and other farm sub-systems. The nutrient linkages lead to farming intensification, food security, income generation and sustainable agriculture (Little and Muir, 1987; Lightfoot *et al.*, 1993; Edwards, 1998; Prein, 2002).

To be sustainable, aquaculture systems should be biotechnically feasible, environmentally sound and socio-economically viable (Shang, 1996). More empirical evidence should be collected on the varied opportunities that aquaculture could provide to improve the income, employment and food consumption levels within households (Ahmed and Lorica, 2002). Widespread adoption of aquaculture on traditional agricultural farms in a number of countries, such as Bangladesh, China, India, Indonesia, Thailand and Vietnam, have shown some early signs of aquaculture's ability to improve productivity, contribute to the diversification of farm operations, and create additional employment and income in a developing country's agriculture (Ahmed and Lorica, 2002). An integrated management approach, with flexible and adaptive technology and farmer-participatory design procedures, has proved that farmers can sustainably and beneficially fit a new aquaculture operation into existing traditional crop-livestock farming practices (Prein *et al.*, 1988). The purpose of this study is to reflect the current status of adoption, modification and potential of IAA systems by small-scale farms in Nongkhai Province.

MATERIALS AND METHODS

In 2007, farm surveys and interviews were conducted in the Muang district of Nong Khai Province, Thailand, aimed at finding out the current management practices of small-scale IAA-systems. The area was selected due to its high density of small-scale IAA farms. Moreover it is a peri-urban

irrigated area, where constraints from water supply and farm inputs were minimized. Thirty three farms and 66 ponds of these farms were selected for collecting data. In addition, integrated water samples from 20 ponds with different management practices were taken from the entire water column near the center of each pond in the afternoon (1300 to 1600 hrs) for water analysis. The chemical parameters of the pond water investigated were total alkalinity ($\text{mgCaCO}_3\text{l}^{-1}$), total hardness ($\text{mgCaCO}_3\text{l}^{-1}$) and chlorophyll *a* concentrations (μgl^{-1}). All were analysed according to standard methods (APHA, 1989). At the time of collecting the water samples, transparency (cm) was measured using a Secchi disc, temperature ($^{\circ}\text{C}$) and conductivity (μscm^{-1}) by a Hach model Sension 5, dissolved oxygen (mgl^{-1}) by a YSI model 52 oxygen meter, and the pH level with a Consort C533 meter. A one-way ANOVA followed by a multiple range test (Duncan New Multiple Range test) were used to determine significant differences ($p < 0.05$) between each water quality parameter from different farm management practices.

RESULTS AND DISCUSSION

The IAA-systems in rural areas of Nong Khai Province involve production systems operated by smallholding farmers and based on locally available pond inputs with a small amount of commercial or supplementary feed for fish ponds. Most farms (40.9%) in studied ranged between 1.6 and 3.2 ha in size, with 2 to 5 ponds per farm. The average area of each pond was 0.32 ha. The water supply for fish farms

in this area was a combination of mainly irrigated water from the Mekong River (81.8%), reservoirs (25.8%) and rain (15.2%). Water supply was not a constraint for fish ponds in the past, but at present some farms face a problem of water shortage due to low water levels in the Mekong River during the dry season. The major fish species cultured in various combinations in these farms include *Oreochromis niloticus* (98.5%), *Barbonymus gonionotus* (53%), Chinese carps (39.4%), *Cirrhinus mrigala* (27.3%), *Cyprinus carpio* (24.2%), *Labeo rohita* (10.6%), *Clarias* sp. (7.6%) and *Pangasianodon hypophthalmus* (3%). Fish stocking strategies in terms of density, number of species and the ratio of each species depended on the availability of seed and the demand. Fish seed was supplied mainly by the government sector (54.5%) and private farms from other provinces (42.4%). The farmers came to realize the effects of seed quality on growth performance of fish from their own experience. The farmers, particularly in northeast Thailand, typically prefer to buy new fish seed from outsiders, believing that purity is more assured. With regards to the stocking strategies based on both the number of fingerlings and the biomass of fish, especially Nile Tilapia, most farmers preferred to stock larger fingerlings, based on biomass of fish to ensure survival and production (Sodsook, 1989). However, the hatcheries in northeast Thailand specialize in the production of 2 to 3 cm fry, while farmers prefer larger fry and are often willing to pay for them (Sodsook, 1989). The main problem of using fry is predation from carnivorous fish. Pond preparation by draining, and the use of piscicides and quicklime to kill remaining fish and eggs

were not adopted by most farmers, and low and unpredictable yields were typical (Edwards *et al.*, 1991). In the rural areas of northeast Thailand, many fish ponds were created after the surface soil was excavated and sold by the landowner for other purposes. Thus, these ponds were not strategically constructed for fish culture, and also most of them were not drained properly. Harvesting was done by seining at intervals, once a year. The most abundant predatory fishes were sand goby (*Oxyeleotris marmoratus*), snakehead (*Channa striata*), climbing perch (*Anabas testudineus*) and walking catfish (*Clarias macrocephalus*, *C. batrachus*).

The main factor affecting aquaculture practices in the area is the cost of feed.

Because the majority of farmers in Asia are poor, many of them cannot even provide supplementary feed to their ponds (Azim *et al.*, 2004). For those who may wish to add supplementary feed, the feed conversion ratio (FCR) has to be taken into account when assessing economic viability. The price of commercial feed has been increasing continuously, while the market price of fish (Table 1) remained constant. In this situation, if the feed conversion ratio (FCR) in fish culture is above 1.5, it may not be an economically viable practice to use the supplementary feed. High FCR leads to higher production costs so ultimately lowering profits, making the use of commercial feed uneconomical for small-scale aquaculture, especially for cash-poor farmers.

Table 1. Sizes and prices of fish cultured in the study area

Species	Size (g)	Farm gate price (baht)	Retail price (baht)
Nile tilapia (<i>Oreochromis niloticus</i>)	< 250 ¹	15	25
	250 to < 400	20	30
	400 to 500	25	35
	> 500	30	40
Common carp (<i>Cyprinus carpio</i>)	< 400	25 to 27	40 to 45
	> 400	35	50 to 55
Thai silver barb (<i>Barbonymus gonionotus</i>)	200 to 350	15 to 20	25 to 30
Chinese carps (<i>Hypophthalmichthys molitrix</i>)	200 to 350	15 to 20	30 to 35
Indian major carps (<i>Labeo rohita</i> , <i>Cirrhinus mrigala</i>)	200 to 350	15 to 20	30 to 35

¹ Sometimes sold for re-stocking Baht 34 = 1 US\$

In IAA-systems, layer chickens were the main livestock integrated with fish culture in most farms (89.4%) due to the demand for chicken eggs in local markets.

The number of layer chickens in most farms (42.4%) was more than 1,500 birds per farm, indicating the potential of chicken farming integration with aquaculture.

The results of water quality monitoring in fish ponds are summarized in Table 2. Total alkalinity, total hardness, dissolved oxygen and pH were within acceptable ranges for tropical aquaculture (Boyd, 1979). The high chlorophyll *a* concentrations in the ponds integrated with poultry (chicken and duck) also indicated the status and potential of poultry in integrated aquaculture, especially in the study area. In general, swine also has

high potential in integrated aquaculture, but there are some constraints in the study area, such as production costs and local market demand. As a result of these constraints, raising a small number of swine may yield lower nutrient concentrations in their wastes when compared to poultry manure (Pillay and Kutty, 2005), which in turn may not provide enough nutrients for the fish ponds, resulting in lower chlorophyll *a* concentrations.

Table 2. Water quality parameters of selected ponds in IAA-systems in Nong Khai Province from February to April 2007, mean \pm SD^a, (range)

Parameters	Type of sub-system				
	Fish integrated with layer chicken (n=7)	Fish integrated with swine (n=4)	Fish integrated with duck (n=3)	Fish integrated with cow (n=3)	Fish integrated with various livestock (n=3)
Total alkalinity (mgCaCO ₃ l ⁻¹)	131 \pm 58 ^b (49 – 199)	68 \pm 26 ^b (40 – 101)	94 \pm 15 ^b (84 – 111)	29 \pm 1.7 ^a (27 – 30)	86 \pm 30 ^b (60 – 118)
Total hardness (mgCaCO ₃ l ⁻¹)	144 \pm 86 (40 – 298)	62 \pm 36 (25 – 110)	109 \pm 45 (80 – 161)	57 \pm 3 (54 – 60)	79 \pm 68 (32 – 158)
Chlorophyll <i>a</i> (μ g l ⁻¹)	439 \pm 298 (155 – 831)	197 \pm 90 (99 – 289)	406 \pm 214 (171 – 588)	105 \pm 16 (90 – 123)	716 \pm 631 (116 – 1374)
Secchi disc visibility (cm)	14 \pm 6 ^{ab} (8 – 26)	26 \pm 6 ^c (19 – 34)	11 \pm 2 ^a (8.7 – 12)	18 \pm 1 ^{ab} (17 – 19)	13 \pm 6 ^{ab} (13 – 26)
Temperature (°C)	35 \pm 2 (32 – 38)	34 \pm 1 (33 – 34)	36 \pm 2 (33 – 38)	37 \pm 1 (36 – 38)	34 \pm 3 (30 – 36)
Conductivity (μ scm ⁻¹)	400 \pm 301 (106 – 748)	157 \pm 70.4 (65 – 236)	325 \pm 176 (186 – 532)	227 \pm 21.9 (202 – 243)	252 \pm 215 (87 – 495)
Dissolved Oxygen (mg l ⁻¹)	7.8 \pm 1.1 ^a (6.2 – 9.2)	6.3 \pm 1.2 ^a (5.2 – 7.7)	8 \pm 0.8 ^b (7.1 – 8.7)	6.7 \pm 0.2 ^a (6.5 – 6.8)	7 \pm 0.4 ^{ab} (6.8 – 7.5)
pH	8.9 \pm 0.9 ^{ab} (7.4 – 10)	8.3 \pm 0.2 ^a (8.1 – 8.4)	9.7 \pm 0.4 ^b (9.3 – 10)	9.4 \pm 0.2 ^b (9.3 – 9.5)	8.6 \pm 0.3 ^a (8.3 – 8.8)

^a Values that are denoted with the same superscript are not significantly different from each other (ANOVA, $p > 0.05$).

To maintain proper fertilization, a Secchi disc reading of 30 cm is recommended (Stickney, 1979); however most of the fish ponds in the study had a Secchi disc reading

of less than 30 cm. This low Secchi disc visibility coupled with high chlorophyll *a* concentration levels may indicate over fertilization or over manure loading.

However, this level of fertility in fish ponds may not reveal the present manure loading rate. The bottom sediment of most undrainable fish ponds may be a major source of nutrients (Knud-Hansen, 1992; Nhan *et al.*, 2006). The high chlorophyll *a* concentration and conductivity of water in most fish ponds show the potential for increasing fish production through fertilization pathways. Fertilization pathways of the fish pond start from the addition of plant waste or manure to the water, followed by decomposition of micro-organisms and the development of natural fish food such as phytoplankton, zooplankton, benthic organisms and detritus (Kwei Lin *et al.*, 1997). An improving of fish stocking practice, optimum density incorporated with proper combination of the species in polyculture may increase nutrient utilization efficiency of the ponds. In addition, use of pond sediment for fertilizing crops is also an alternative to nutrient recycling.

The avian influenza crisis in the region has played an important role on the culture practices due to deaths and the culling of chickens, leading to limited supply of waste for pond inputs. Some farmers have turned to using supplementary feeds (farm-made feed), while others have tried to continue using manure by buying chickens from outside their area. The use of lower

nutritional value manure, such as cow manure has increased. The cost of cow manure and layer chicken manure are approximately 1 and 2 baht per kg, respectively. The price differentiation of the two manures may respond to the demand for chicken manure by farmers accustomed to using manure as feed, and also on the nutrient content as the nitrogen and phosphorus levels in chicken manure are about 2 times higher than those in cow manure (Schroeder, 1980).

Management practices for livestock/fish sub-system can be categorized into 3 types (Table 3). Type I fish farmers grow both fish and livestock, and production is sold to local markets by the farmers or by merchants acting as middlemen. Type II farmers grow both fish and livestock, while production is sold to merchants as middlemen. Type III farmers grow livestock, while the merchants rent the fish ponds for fish cultivation. Partial harvesting of the fish stock depends on demand from both the local markets and those from nearby provinces. Harvesting is done by the farmer themselves (involving seine rent and labour hire) or by the merchants. When the merchants do the harvesting, the farm gate price is reduced by about 2 baht per kg. Non-marketable size fish are sometimes sold as seed or restocked in other ponds in the same farm.

Table 3. Management practices of livestock/fish sub-system in Nong Khai Province

Activity	Partner		
	Type I	Type II	Type III
Livestock rearing	Fish farmer	Fish farmer	Fish farmer
Fish culture	Fish farmer	Fish farmer	Merchant
Marketing	Fish farmer/Merchant	Merchant	Merchant

There are many varieties of crops usually grown in most farms for cash and household consumption (Table 4). However, efficient development of the IAA-systems depends on an understanding of the resource base used by aquaculture (Nhan *et al.*, 2006). There is evidence of utilization of nutrient-rich water from fish ponds being used by some farmers to irrigate these crops by means of irrigation systems using small pumps and piping. One such example is that of farmers involved in beef production cultivating *Pangola* grass in paddy fields as feed for their own cows and also for sale. There is evidence of diversification in the present farming in this area, so IAA-systems still have a potential in the future due to their adaptive flexible characteristics. Meanwhile fish pond inputs in this area may be more diversified such as using more green manures.

Table 4. List of vegetation partially utilizing water from fish ponds in Nong Khai Province

Herbs and Vegetables	Fruit trees	Grass	Miscellaneous
Galanga, Ginger, Maize, Corn,	Banana, Papaya, Coconut,	Bamboo, Pangola Grass,	Tobacco, Eagle Wood,
Lemon Grass, Cucumber, Yard	Guava, Jack Fruit,	Guinea Grass, Paragrass,	Eucalyptus, Betel Nuts,
Long Bean, Sponge Gourd,	Mango, Dragon Fruit,	Rice	Rattan Palm, Thai Copper
Cayenne Pepper, Chili Spur Pepper,	Pummelo, Shaddock,		Pod
<i>Neptunia oleracea</i> Lour, Lettuce,	Longan, Tamarind,		
<i>Cratogeomys formosum</i> , <i>Heliotropium</i>	Averrhoaceae, Santol		
<i>indicum</i> L., Water Spinach,	(Tag.), Marian Plum, Wax		
Pumpkin, Leech Lime, Brenjal,	Apple, Star Gooseberry		
Tomato, Kitchen Mint, Shallot,			
Sweet Basil			

CONCLUSION

Integrated aquaculture still plays an important role in rural farming in Nong Khai Province, Thailand. The production system operates at a small-scale level, based on locally available pond inputs. Fish culture needs to be integrated with other agricultural activities, both livestock rearing and cropping, due to the cost and availability of commercial fish feed being a major constraint in rural areas. Participatory farmer assessment revealed that IAA-farmers considered

livestock, not ponds or crops, as the principal sub-system. However, the benefits from fish production are attractive to all farms. The constraints in the availability of input resources and marketing are the main factors affecting diversification of agriculture-aquaculture systems in this area. Agriculture-aquaculture systems have been adopted well in rural areas by farmers. However, for the purposes of integration, the improvement of sustainability, resource efficiency and productivity have not been clearly evaluated.

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