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Contents

Note

Research managers, researchers, agricultural development planners, extension advisers and leaders of farmer groups would find this issue of the Journal helpful.

In the next 25 years, Earth is expected to have 2 billion more people. A population of 8 billion will need to be matched by the production of more food that every person can afford. Opening more arable land and using more fresh water are no longer desirable options. Intensification seems necessary, but it raises concerns over ecological, economic and social sustainability. As well, the poorer groups in society may not have access to the capital or knowledge needed to implement advanced, intensive, usually mono-culture farming techniques. Integrated farming, an old practice in Asia, offers new hopes.

This issue contains 5 practical on-farm studies on integrated farming systems, 4 in Asia, 1 in Africa. Results from two projects that aimed to increase the efficiency by which Asian integrated pond-dike systems use resources, especially on-farm resources, are described. The Bangladesh, Thailand and Vietnam studies show that integration and diversification increase farm productivity and incomes. As part of the project, farmers and scientists worked together to identify a range of technologies that improve livelihoods and reinforce the good impacts of integrated aquaculture–agriculture systems on the environment.

The studies were under two projects called “POND” supported by Wageningen University of The Netherlands and “Pond-Live” funded by the European Union. The first article explains the project approach. The last article describes a number of economic and social forces that are exerting important influences on farm household strategies and, in general, agricultural development in Vietnam and the role of integrated aquaculture-agriculture in such situation. The studies were carried out by staff and students of the Asian Institute of Technology, Bangladesh Agriculture University, Can Tho University, Thailand’s Sisaket College of Agriculture and Technology, Stirling University and Wageningen University. For research managers and field researchers, details of the results are in the book: Fish Pond in Farming Systems (2007). Wageningen Publishers.

Approaches to understanding pond-dike systems in Asia: the POND-LIVE project approach

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The practice of on-farm storage and use of water and nutrients in ponds is becoming widespread in several parts of Asia. The utility and importance of ponds, and the water they contain, vary greatly between locations and between households at the same location. The concept of a 'pond-dike system' in which the dike or the area surrounding the dike is used for horticulture based on water from the pond is best described for China but is also getting more common in various parts of south and southeast Asia. In China, polyculture has been traditionally practiced in ponds that are also used as sink for nutrient sink or storage for water to irrigate the crops grown around the pond.

Analysis of practices elsewhere in Asia has been limited despite ponds being promoted as a focus for aquaculture development in some areas. In theory, integrating an aquaculture component into a farming system may result in more efficient and ecologically sound practices. Such practices may produce a range of products without major negative environmental impacts. Such diversification could improve the resilience of vulnerable households; they have other crops to fall back to should one of the crops fail.

Pressure to intensify the use of land, water and other resources is increasing throughout Asia. Farming households seek to improve their livelihoods by exploiting new opportunities that growing and dynamic economies offer. Understanding the roles that pond-dikes play for both poor and better-off households located at varying distances from growing urban centres was seen as an important priority. The importance of ponds in improving nutrient efficiency and reducing pollution from nutrient discharge was considered a central theme. In addition, our insights into the roles that products and services derived from pond-dikes play on peoples' lives needed updating. Are incomes improved? Do families eat better? Does the pond and its surrounding crops smooth out seasonal shortages in food and cash. Do they foster goodwill among people in the farming community? What characteristics identify households that manage their systems intensively and what factors constrain other households from doing the same?

These questions led to the formulation of a research project called POND-LIVE that was funded by the European Union with partners from the Netherlands, UK, Thailand, Bangladesh and Vietnam. A major objective was to improve the impact of integrated aquaculture-agriculture (IAA) systems by combining the lessons learnt from all three Asian project sites into generic messages of value to a broader group of people and institutions involved in IAA-farming.

Approach

The POND-LIVE projects followed a Participatory Learning in Action approach composed of six phases (Figure 1.1). Intermediate results were presented at progress and dissemination workshops to ensure that existing information on pond-dike systems in the study areas were utilized, and that research results were placed within a wide conceptual framework.

Phase 1: Secondary data were collected from literature, experts, local resource persons, and national policymakers. The data were used to select three research areas with integrated pond-dike systems.

Phase 2: Prevailing problems and constraints of IAA-systems and key research and development issues were identified and prioritised through Participatory Community Appraisal (PCA) followed by State of the System (SoS) workshops.

Phase 3: A structured household level analysis to assess how factors such as the level of integration between IAA-farming components, well-being of households and location in relation to urban centres influence the role of the pond within the farming system.

Phase 4: A monthly household panel approach to identifying and describing the impacts of pond-dikes on seasonal vulnerability and resource use.

Phase 5: An integrated process of on-farm participatory trials supported by on-station technical research. The on-station research focused on pond nutrient dynamics and the value of pond sediments as fertilizer. Research findings were shared through regularly held participatory workshops.

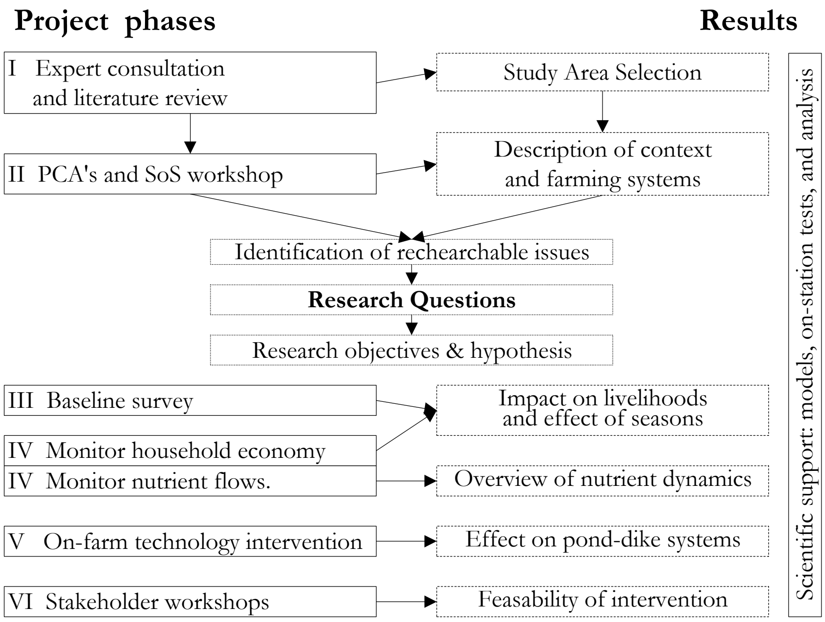

Figure 1.1. Schematic representation of the POND research approach.

Phase 6: Sharing and dissemination of research outcomes with farmers and other local stakeholders. Policy workshops at district, provincial and regional level were organised towards the end of the project using extension material developed during the project.

The program consisted of several PhD projects, each formulated around two to three years of fieldwork focusing on monitoring, on-farm participatory trials or on-station experiments. Additional Ph.D. projects, funded through other sources, widened the overall context, broadening perceptions and deepening insights. This approach of combining PhD research with on-farm participatory experiments proved valuable as it created new technologies produced scientific papers, and trained researchers, development workers and farmers. More results and details can be found in a volume presenting and discussing the project results (Zijpp et al, 2006).

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Zijpp A.J. van der, J.A.J. Verreth, Le Quang Tri, M.E.F. van Mensvoort, R.H. Bosma, M.C.M. Beveridge (editors). 2006. Fishponds in Farming Systems. Wageningen Publishers (in press).

The contribution of fish ponds to nutrient cycling in integrated farming systems

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Fish, shellfish or shrimp are often considered the only beneficial products from aquaculture. This leaves out other important benefits ponds provide in integrated aquaculture-agriculture (IAA) systems. These include on-farm water storage, trapping of nutrients in pond sediments and re-use of on-farm organic wastes. Low priority is given to the use of agricultural by-products as inputs to ponds because farmers believe formulated feeds boost pond production beyond that achievable with fertilization only. As a consequence, the potential value of agricultural by-products through pond aquaculture and its effects on nutrient use efficiencies in mixed aquaculture-agriculture farms remains insufficiently explored.

In a study at the World Fish Centre in Egypt, the fractions of nutrients from agricultural by-products applied to ponds ending up in fish biomass or accumulating in sediments were measured. The value of pond sediments as fertilizer for terrestrial crops was evaluated. In addition, the effects of incorporating pond aquaculture in Kenyan highland farming systems on nutrient use efficiency and overall farm productivity were explored.

The amount of sediment and nutrients accumulating in ponds during a 5-month tilapia production cycle were quantified monthly by measuring changes in sediment depth, sediment bulk density and nitrogen (N), phosphorous (P), potassium (K) and organic carbon (OC) concentration. Four treatments, using as nutrient source chicken manure or pellet feed and stocking 1 or 2 tilapias m^{-2}, were tested. At harvest, the accumulated sediment was transferred to experimental corn plots. Corn yield from plots fertilized with chicken manure or sediment from pellet-fed ponds was compared to production based on a standard inorganic fertilizer dose (positive control) or receiving no fertilizer at all (negative control).

To explore the feasibility of developing IAA systems in existing agricultural farming systems, different tilapia production scenarios were drawn. We based the scenarios on information found in literature. For each scenario, the nutrient flows through the production systems were calculated. This information was integrated into a database of nitrogen flows though existing farming systems in Kenyan highlands. Four farming systems, each representing a different agro-ecological zone, were examined. Nutrient balances of the resultant IAA-systems were compared with those of agricultural farming systems currently practiced (obtained from NUTrient MONitoring or NUTMON survey data sets) and the changes in farm nutrient balances were quantified.

Fish survival and production were similar in ponds receiving comparable N-inputs either in the form of chicken manure or pellet feed. About 125 – 300 kg N, 1.8 – 5 tons organic matter and 50 – 125 kg K accumulated per ha in pond sediments during the 5 months culture period (Table 1). The amount of available P that accumulated was negligible. Statistically, the amounts of N, K, P and OC that accumulated in pond sediment and that can be extracted for crop production was not different between ponds fertilized with chicken manure or fed with pellets ($P > 0.05$). During the 5-month culture period, per hectare 75-170 ton of sediment accumulated at the pond bottom. A large fraction of the nutrients entering through influent water and fertilizer or feed inputs are trapped in the accumulated sediments. The accumulated sediment is rich in nitrogen, exchangeable potassium and organic matter. As such it has a high potential as a nitrogen and potassium fertilizer. An additional advantage of the use of pond sediment is its richness in organic matter, which also functions as a soil conditioner. In heavy clay and in light sandy soils, the organic matter can improve the soil structure and increase the water holding capacity. Also phosphorous accumulates in the sediment, but mostly in a non available form, explaining the low levels of available phosphorous reported in Table 1.

In Egyptian aquaculture, the accumulated nutrients in a 1 ha pond potentially meet the nitrogen and potassium requirement of a 1.5-ha crop of maize, provided phosphorus fertilizer is added. When doing so, crop production was similar ($P > 0.05$) in plots fertilized with pond sediments and in plots fertilized with the standard inorganic fertilizers (Table 2). The results indicate that, pond sediment is an excellent crop fertilizer, regardless of whether the nutrient input source is chicken manure or formulated commercial feed (Muendo 2006).

In the 4 agro-ecological zones of the Kenyan highlands, N-depletion in agricultural soils is common. By adding a fish farming component to the farming systems, the N-depletion is reduced by 23-35%, depending on the agro-ecological zone. The results show that integration of aquaculture in the farming system allows to use nutrients that otherwise would be lost during storage or use on land (Table 3). In addition, by positioning the pond at the lowest point of the farm, nutrient losses due to erosion are also minimized. Although the results are promising from a nutrient point of view, research on labor availability and seasonal peaks in work load is recommended to evaluate the overall feasibility of integrating pond farming in farming systems in the Kenyan highlands.

References:

Muendo, P.N. 2006. The role of fish ponds in the nutrient dynamics of mixed farming systems. Ph.D. thesis. Wageningen University, Wageningen, The Netherlands. pp. 120.

Table 1. Sediment and nutrients at the end of the culture period. CM = chicken manure; P = pellet; 1 = stocking density of 1 fish m^{-2}; 2 = stocking density of 2 fishes m^{-2}. The experiments were carried out in 200 m^2 ponds. Treatments were not significantly different.

	Treatments			
Parameters	CM-1	CM-2	P-1	P-2
Accumulated sediment quantity (tons $pond^{-1}$ cycle)	3.1	1.5	2.8	1.67
Nitrogen				
Concentration at harvest (g kg^{-1})	1.9	1.9	1.7	1.6
Quantity in accumulated sediment (kg ha^{-1})	295	143	238	124
Organic carbon				
Concentration at harvest (g kg^{-1})	14.5	12.5	11.7	12.7
Quantity in accumulated sediment (tons ha^{-1})	2.3	0.9	1.6	1.1
Available phosphorus				
Concentration at harvest (mg kg^{-1})	6.3	3.8	3.3	3.5
Quantity in accumulated sediment (kg ha^{-1})	0.97	0.28	0.46	0.29
Potassium				
Concentration at harvest (mg kg^{-1})	72	77	74	73
Quantity in accumulated sediment (kg ha^{-1})	112	58	104	61

Source: Muendo, 2006

Table 2. **Maize production in unfertilized plots, plots fertilized with inorganic fertilizer and in plots fertilized with pond sediment.**

Nutrient input	Fertilizer type (kg plot^{-1})	Total plant biomass (kg plot^{-1})	Grain weight (kg ha^{-1})
Pond sediment (from pellet fed ponds)	28.7	7.5[a]	6.3
Pond sediment (from chicken manured ponds)	26.7	6.0[a]	5.0
Inorganic fertilizer	20.6	5.3[a]	4.4
None	11.2	2.5[b]	2.1

Values in the same column with no superscripts in common are significantly different. In case of no significant difference, no superscripts are given.
Source: Muendo, 2006.

Table 3: **The effect on production and N-depletion of integration of aquaculture in farming systems in Kenyan highlands.**

Existing farming system	No pond	With pond	% change
Productive area (ha)	1.41	1.35	**-4**
Input of N for primary production processes (kg/ha)	183	265	**45**
Harvested green crops (kg N/ha)	19	24	**26**
N-depletion in agriculture soils (Kg N/ha/jaar)	116	75	**-35**

Source Muendo, 2006

Improving the contribution of fishfarming to livelihoods in Northeast Thailand

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As in other SE Asian countries fish trapped and raised in multi-purpose ponds after the seasonal floods contribute to household food security in Northeast Thailand. Here, ponds are mostly located on lowland plots at some distance from the farm homestead. While in, say, Bangladesh and Vietnam the production of stocked fish contributes much to farm household income, in Northeast Thailand the use of ponds for fish culture needs much improvement.. In 2003, through participatory assessments, the POND-LIVE project identified the adaptation of technologies for nursing of fingerlings before stocking, and fattening them according to local needs as a priority for aquaculture development. In farmer-led experiments the feasibility of nursing mono-sex reversed Tilapia and using various types of nutrients inputs for fattening were tested.

Methodology

In 9 villages, belonging to 6 communities of Northeast Thailand, 38 men and 5 women farmers took part in the trials using sex-reversed Tilapia. The on-farm experiment had two phases: nursing and fattening. Monitoring workshops were held each month during nursing and every other month during fattening to gauge progress and to adjust the dosage of the feed/fertilizer (including manure). Twenty-nine farmers accepted fish sampling for length and weight measurement before the monitoring workshops.

The brood-stock provided by the project was raised in hapas in different ponds and fed with a mixture of fine rice bran and piglet weaning feed. The feeding was either done by the pond owner or on-turn basis by a group member.

For fattening, three treatments were applied (Table 1). The nutrient inputs available in the control (T-1) were termites, chicken manure, cow dung, compost, rice bran, vegetable waste and household waste. The goal of T-2 was to show that fish can grow using fertilization with manure from cattle, pig or chicken and urea, and of T-3 to demonstrate that supplementing with a home compound feed was commercially viable. The recommended ingredients of the home compound feed were: rice bran, fish-meal and vegetables. If urea, or the money to buy it, were not available farmers used NPK fertilizer or manure.

The final total weight and the probable cash income was calculated estimating the average weight of a sample of 50 fishes and assuming a survival rate of 80% and a market price of 30 baht/kg^{-1}. Partial budget considered the cost of the fry, their feed and the real or opportunity cost of all feed, including manure and wastes.

Table 1. The 3 treatments of on-farm fish fattening trials in Northeast Thailand

Treatment	T-1	T-2	T-3
Fish.m^{-2}	2	4	6
Feeding method	Traditional with on-farm available wastes	Green water using fertilizer	Green water using fertilizer, supplemented with homemade feed

Results

During nursing, the fish gained around 1 $g.week^{-1}$. After 8 weeks the average weight was 9 g. The average survival rate varied from 53 to 100% and the cost for feeding from 0.11 to 0.36 Baht per $fingerling^{-1}$. The variations were due to fish escaping from non-stabilized hapas and to not following the feeding strategy. Perhaps the quantity of feed should have been adjusted more frequently; more workshops among the farmers and researchers could have given a better indication. At present many farmers still use hapas for nursing and they are teaching the technology to neighbors, friends and relatives.

Either method of improved fattening increased average body weight (ABW) and doubled gross margins (Table 2). Due to the large variation between replicate farms none of the observed differences was statistically significant. The distance between the pond and the farm did not affect the gross margin, but the farmers' frequency of visiting the pond improved the gross margin (r^2=0.4). The use of urea was a correlated with ABW (r^2=0.37), which in turn explained the variation in the weighted gross margins (r^2=0.89). Although the estimated gross margin from fattening the fish was negative for some farmers, all farmers perceived a benefit. Reasons for this discrepancy are the fact that an opportunity cost for on-farm wastes was included while the fertilizer value of the pond water and sediment was not considered in the gross margin analysis. A complete farm budget could show a more positive picture.

Table 2. The number of farmers (n) and some statistical parameters for the estimated average body weight (ABW), the weighted cost and the weighted gross margin (Baht/fish stocked) of the fattening trial.

	ABW (g)			Weighted cost *			Weighted gross margin *		
Method	T-1	T-2	T-3	T-1	T-2	T-3	T-1	T-2	T-3
n	7	14	8	7	14	8	7	14	8
Mean	72	95	114	1.28	1.24	1.79	0.45	1.04	0.95
SEM	17	11	15	0.17	0.09	0.24	0.48	0.29	0.48
Min	19	29	63	0.71	0.77	0.88	-1.05	-0.75	-1.76
Max	134	156	162	1.97	2.15	3.28	2.51	2.97	2.07

* The total cost and the gross margin were weighted by the number of fish stocked.
SEM = Standard Error of Mean; 1 Euro = 48 Bath

The farmers recognized the importance of nursing the fingerlings before stocking the ponds. For fattening, almost 40% of the 36 farmers preferred T-2 because it saved labor time and kept expenditures low. The fish grew well and the green water could be used for irrigation. To keep costs down but maintain or improve fish growth 25 % of the farmers proposed lower fish densities for T-3 to 4 fish m^{-2}. They found that working alone made it harder to improve their aquatic system than the other components of their farm, and that working in groups and sharing knowledge improved their learning.

Conclusion

In low-cash economies, cost-return ratios are crucial. The farming systems used by poor farmers show a better cost-return ratio than the systems applied by richer farmers, both in Bangladesh (Wahab et al, this number) and Northeast Thailand. The Thai study showed that giving careful consideration to available on-farm inputs and pond production strategies makes it possible to further improve the cost-return ratio.

The authors are grateful for the financial support of the EC (ICA4-CT-2001-10026), the encouragement of Ms Cornelia Nauen, the availability of Sisaket College of Agriculture and Technology, the enthusiasm of the fieldworkers, and the generous participation of the farm households.

Benefits of pond-dike systems in Bangladesh

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Agricultural production depends on supplementary nutrient inputs in the form of fertilizer or feed. The wise utilization of nutrient resources by farmers would contribute much to the achieving a sustainable agriculture. Pond-dike systems offer opportunities to increase the value of farm waste and the utilization of nutrients from these and other on-farm resources.

Pond-dike systems

In pond-dike systems fish are grown in ponds while the dike is planted to vegetable or fruit trees. Some space above the water edges are planted with trailing plants on trellis made of scraped fishing net, bamboo or wire for aerial support. In turn, nutrient-rich pond boosts crop production on the dike or in the pond's vicinity, and wastes or by-products from crops can be used as fish feed and pond manure. With this system, nutrients can be cycled between aquatic and terrestrial farming components, improving the overall on-farm nutrient efficiency and reducing dependence on external inputs. It promotes a sustainable rural livelihood. Well developed and managed pond-dike systems contribute to a better environment, enable farmers to earn more income and improve the diets of small holder families.

Pond Live Project

Initial research on pond-dike systems was carried out in some Asian countries through the Pond Live Project (EC-grant) that involved European and Asian universities, in the period 2001 - 2005. Part of the program was the conduct of field trials in different villages in the Mymensingh region in Bangladesh. The overall objective of the program was to improve the use of nutrient in integrated pond-dike systems. The results were encouraging.

Change in strategy

Poor farmers in Bangladesh rarely apply feed or fertilizer for fish production because they use the limited amounts of nutrients available to grow vegetables or field crops. As a result, the production of aquaculture is lower than expected. The project goal was to make farmers convinced of the benefit to crop production from using nutrients accumulated in their fishpond and to value the contribution of crop wastes as nutrient input to fishponds.

Improved aquaculture system

An on-farm trial compared the productivity of three polyculture systems in ponds. System-1 was a traditional carp polyculture (TCP) production system, receiving feed and fertilizer irregularly and in low quantities. System-2 was similar to system-1, but an additional 10% mono-sex all male genetically improved farmed tilapia (GIFT) (TCP+10%T) were stocked. System-3 was similar to system-2 but now feeding and fertilization (TCP+10%+FF) levels were properly set and regularly applied. The fish production obtained within a 10-month culture period by systems is shown in Table 1.

Table 1. Species-wise mean values of gross yield (kg ha^{-1}) under different aquaculture systems (results from 3 replicate ponds per system).

Species	System 1(TCP)	System 2 (TCP+10%T)	System 3 (TCP+10%T+FF)
Silver carp	690	985	2,483
Catla	222	217	605
Rui	535	373	1,123
Mrigal	174	213	422
Common carp	132	112	279
Thai puntius	94	100	174
Total carp	1848	1999	5086
Tilapia	0	84	226
Total output	1848	2083	5312

The yield obtained in System-3 was 2.87 times higher than the yield in System 1. The addition of tilapia without improving on feed and fertilizer input in System 2 only resulted in a small increase in production compared to System-1 (Table 1). In addition, the quality of the pond sludge, containing accumulated nutrients during the production cycle was better in System 3 than in Systems 1 and 2.

Use of pond mud for vegetable production

Poorer farmers are usually reluctant to grow vegetables because they cannot afford to buy the inputs. To demonstrate the beneficial effect of nutrients contained in pond mud on vegetable production, mud from the 3 different systems was mixed at 33, 66 and 100% within the 10-cm top soil of production plots of red amaranth (*Amaranthus cruentus*), a leafy vegetable. In addition, farmers cultivated red amaranth in the traditional way without applying fertilizer or pond mud to their plots (= control). The average yield of red amaranth in the control plots was 0.16 ton per ha. This was much lower than the production obtained in plots receiving pond mud, where the lowest production was 1.15 and the highest was 6.65 ton per ha (Table 2). The results showed that pond mud is a good fertilizer; red amaranth production increased with increased application rates of pond mud in the plots. Pond mud from System-3 ponds was a better fertilizer than mud from System-1, which was better than mud from System-2. Stocking 10% GIFT tilapia in System-2 caused less nutrients to accumulate in the mud. The mud from the ponds with the increased feed and fertilizer rates of System-3 gave the best performance (Figure 1). In summary, the farmers learned that addition of pond mud in the dike plots increased vegetable production and that the quality of pond mud as a fertilizer is strongly influenced by the production system.

Table 2. Yield of red amaranth (mean values) as influenced by pond mud from different culture systems and different mixing rates

Parameters	Systems			Different mixing rates (%)		
	1	2	3	33	66	100
Yield (ton per ha)	4.19	1.15	7.41	1.76	4.33	6.65

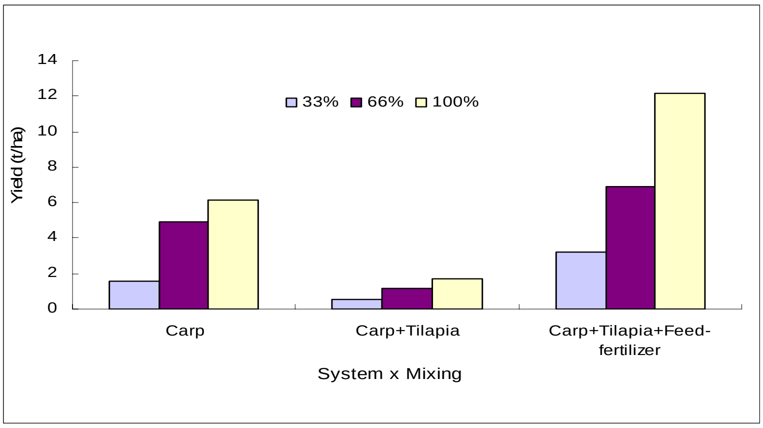

Figure 1. Yield of red amaranth in different combination of farming system and mixing rate of pond mud in production plots.

Conclusion

Pond-dike systems have a great potential in a resource constraint country such as Bangladesh. To derive the maximum benefit of pond-dike systems more research is essential, especially to identify culture systems that yield good quality pond mud for crop production. Because the collection of pond mud is labor intensive, research to improve mud collection, mud storage and timing of collection is also recommended.

Common carp increases rohu production in farmers ponds

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Rohu (*Labeo rohita*), catla (*Catla catla*) and mrigal (*Cirrhinus cirrhosus*) are traditionally popular in south Asian pond polyculture (Kanak et al., 1999), contributing more than half of the total inland aquaculture production in this region (FAO, 2005). Among these three species farmers prefer to stock rohu because it enjoys a higher consumer preference and commands a higher price (Dey et al., 2005). Therefore, rohu has been used as a popular polyculture species in this region especially in Bangladesh and India. However, in most cases, farmers find its slow growth rate disappointing and complain of the complexity of the polyculture system. In very few cases farmers do obtain higher production, usually when they culture rohu with some bottom feeder such as common carp. But they do not fully understand the real cause of higher or lower growth rate. To help them, the Pond-Live project sought to understand the multi-species fish farming system. Multi-species fish farming systems are complex, therefore, a simple two-species fish farming system with rohu and common carp was chosen as a starting point. This article describes and explains the effects of common carp on the growth and production of rohu in pond aquaculture system.

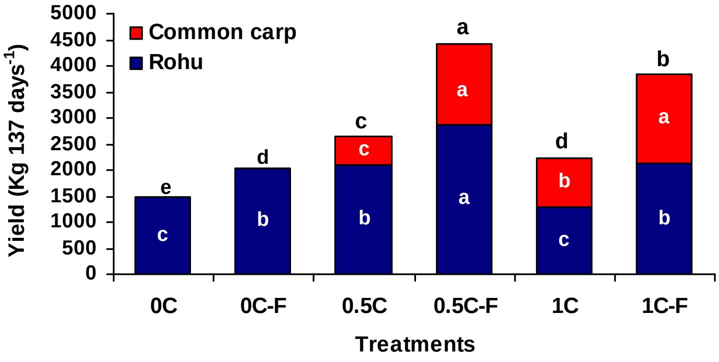
Methods

The investigation was conducted in 18 earthen ponds of 100 m^2 and 1.2 m depth. All ponds were stocked with 1.5 rohu m^{-2}. Common carp was stocked in three densities (0, 0.5 and 1 m^{-2}) in both fed and non fed ponds. The combinations of common carp and artificial feed resulted in six treatments: rohu alone with no feed (treatment 0C), rohu alone with feed (0C-F), rohu plus 0.5 common carp m^{-2} with no feed (0.5C), rohu plus 0.5 common carp m^{-2} with feed (0.5C-F), rohu plus 1 common carp m^{-2} with no feed (1C), and rohu plus 1 common carp m^{-2} with feed (1C-F). All treatments were in triplicate. All ponds were fertilized with decomposed cow manure, urea and triple super phosphate before starting the experiment and thereafter at fortnightly intervals throughout the study period. Water quality, natural food availability and gut content were investigated fortnightly. The same treatments were also tested in the simulated ponds (aquarium having nearly similar pond environment, see picture) to observe directly the influence of common carp on the feeding behavior of rohu.

Simulated ponds that were used to observe directly the influence of common carp on feeding behaviour of rohu

Result

The effect of stocking common carp at different densities in rohu ponds on food availability, food intake, growth and production revealed some synergies, in other words, the individual effects enhanced each other's positive impacts. These effects were stronger in ponds with 0.5 than 1 common carp m^{-2}. Rohu production increased 1.4 times and total pond production doubled in ponds with 0.5 common carp m^{-2} compared to ponds with no common carp (Fig.). Artificial feed had a positive effect on rohu production as well as total production. These effects of artificial feed were positively influenced by the presence of common carp. The practical recommendation from the above results is that farmers can achieve higher rohu production as well as total pond production if they stocked 15,000 rohu and 5,000 common carp per ha of pond area. A gross production of 11,800 kg ha^{-1} yr^{-1} could be obtained in fed pond with this stocking.



Total yield of fish and relative contibutions of rohu and common carp in six treatments. Letter above bars relate to total yield. Letter within bars relate to rohu or common carp yield. Yield with no letter in common are different.

Direct observations of the feeding behavior of rohu and common carp using a video camera confirmed that rohu is a column feeder, mainly feeding on plankton, and common carp is a bottom feeder mainly feeding on benthic macro-invertebrates. Rohu spent 47-52% of the total time in the company of common carp and this association increased rohu's activity by 51-62%. The net result was that rohu spent relatively more time grazing near the bottom instead of in the water column where the density of zooplankton was lower. In short, in the presence of common carp, rohu ate more zooplankton, which made it grow better.

Conclusion

The common carp enhanced the release of nutrients from the sediment, stimulating phytoplankton productivity and accelerating the use of nutrients by organisms in the food chain. Stocking 5,000 common carp ha^{-2} had a pronounced effect on nutrient cycling: it had the effect of transforming at a faster and higher rate the nutrients in the pond into fish flesh. In this experimental set-up, stocking of 10,000 common carp ha^{-2} can be considered as over-stocking. At this high density fish production was lower and more nutrients accumulated in the sediment than with 5,000 common carp ha^{-1}. In conclusion, polyculture of 5,000 common carp and 15,000 rohu m^{-2} with artificial feed was the combination in which both rohu production and total pond production were highest.

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Improving pond-dike farming systems in the Mekong Delta, the Can Tho approach.

Dang Kieu Nhan, Le Thanh Duong, Le Thanh Phong, Roel H. Bosma and Marc C.J. Verdegem

Fish plays an important role in the livelihood strategies of rural households of Southeast Asia, as a source of protein and as a component of family income. In the Mekong delta of Vietnam, wild fish resources have declined since the early eighties because of over-fishing and the expansion and intensification in rice cultivation. Fishponds, recently introduced, represent a major strategy to provide low-cost animal proteins and generate income for poor households. Aquaculture started with the capture and culture of indigenous fishes in rice fields or multipurpose ponds. In the mid-eighties, farmers began transforming the rice fields into orchards with ditch-dike systems, producing fruit and fish. Or modifying the rice fields into rice field-ditch-dike systems, growing rice, fish and fruit trees at the same time. The Vietnamese government promoted the development of aquaculture both as a specialised practice and as integrated agriculture-aquaculture (IAA) systems by providing credit, extension services and supporting hatchery establishment.

Various studies report that fish harvested from ponds recover a small fraction of nutrient inputs. A large portion of the nutrient inputs accumulate in the pond sediment or are discharged through pond water exchange. If this occurs in the ponds along the Mekong delta, improved management of the system could give a dual benefit: maximizing the benefit to farmers while minimizing adverse impacts on the Mekong river ecosystem. In the Delta most farmers have easy access to open water resources and depend on gravity for pond water exchange. They tend to use water lavishly because, as yet, they see no scarcity of it

Fish production systems

Integrated fish farming systems are commonly practiced in the delta. Nhan et al.[1] identified three major integrated pond systems: low-water-exchange ponds in fruit-dominated area (System 1), low-water-exchange and feed-fed ponds in rice-dominated area (System 2), and high-water-exchange and manure-fed ponds in rice-dominated areas (System 3). In the fruit-dominated area, farmers grow fish in sub-optimal conditions. Ponds are narrow, shallow, and shaded by canopies of fruit trees. The food input levels and fish yield were low. In the rice-dominated areas, farmers grow fish in wide or deep ponds receiving home-made feed (System 2) or livestock manure inputs (System 3). System 3 discharged large amounts of N to rivers and canals, due to high water exchange rates practiced to dilute metabolites and provide oxygen when more wastes are loaded.

Pond optimization strategies

A participatory approach was adopted to develop the technology that would improve nutrient use efficiency of the pond systems. In the fruit-dominated area, reducing water exchange rates and adding manures or inorganic fertilizers, and appropriately pruning the branches of fruit trees was advised to improve fish yield and nutrient accumulation in pond sediments. In the rice-dominated area, where farmers tend to intensify pond farming or to use the pond primarily for disposing of wastes, manure input levels should be adjusted to the water quality and fish stocked. Stocking appropriate fish species is a way to make pond ecosystem better.

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[1] *Dang K. Nhan, Ana Milstein, Marc J.C. Verdegem, Johan A.V. Verreth, 2006. Food inputs, water quality and nutrient accumulation in integrated pond systems: a multivariate approach. Aquaculture 261, 160-173*

On-farm trials showed that reducing pond water exchange rates according to pig manure input levels reduced pond N discharge (Fig 1). In System 1, increasing the manure input to ponds from 83 to 471 kg N ha^{-1} yr^{-1} and reducing the water exchange rate from 7.9 to 2.6 % of pond volume per day improved fish yield. In System 2, reducing the water exchange rate from 1.5 to 0.6 % volume per day and decreasing manure input levels by half improved pond primary productivity but reduced fish yield slightly. In system 3, reducing water exchange rate from 21.4 to 5.3 % volume per day and partly substituting manure input by supplemental feed improved fish yields. Moreover, analyses (by multiple regression) showed that fish yields in IAA-ponds were significantly and positively affected with inputs from feed and livestock waste and stocking rates, and negatively affected by water exchange rates. High feed input levels and high stocking rates, however, reduced the economic returns of the pond culture.

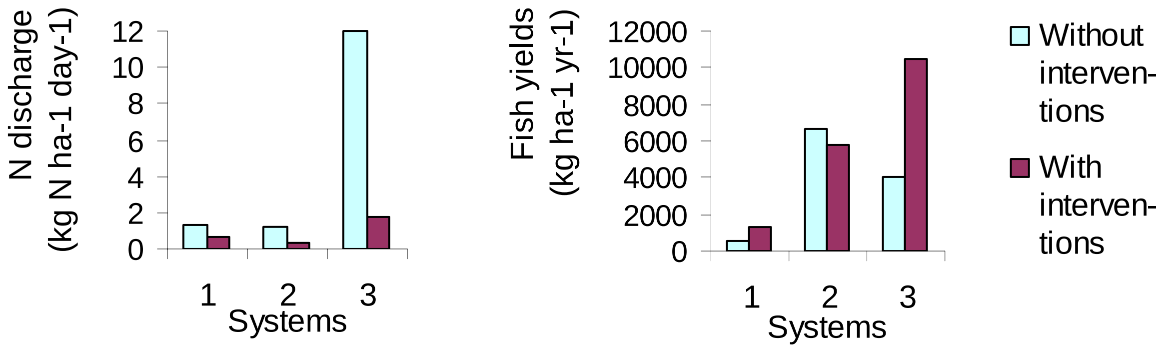

Figure 1: Effects of reducing pond water exchange rates to pig manure input levels (two pond interventions) on fish yields and pond N discharge by IAA-systems.

A large portion of added nutrients accumulate in the sediment. Farmers use this pond mud to fertilize their crops. The mud can help maintain soil fertility because ponds in the delta hardly receive rich alluvial deposits because of the construction of flood protection dikes. The results imply that farmers should maximize integration between pond with crop, animal components and human activities, for better use of on-farm nutrient resources and for higher profitability while safeguarding the environment.

Farmers and extension workers stressed the importance of integrated systems for socio-economic reasons and ecological friendliness. Farmers take up IAA-farming to increase resource use efficiency, improve family nutrition and increase household income. But they may not be able to adopt IAA-farming because the technology is not available, they have limited household resources (land, labor, capital), and the soil and water resources are not suitable. IAA-farming could be promoted by improving information access and enhancing technical training, as the aquaculture know-how of most farmers in the Mekong delta is still limited. IAA-components are strongly interdependent so that farmers need to acquire better farm management skills to enhance the positive interactions among IAA-components for optimally efficient use of production resources (in other words, under given circumstances, they obtain the best result from the combination of labor, capital and physical inputs).

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Fuzzy pathways to farm development in Vietnam

Roel H. Bosma, Le Thanh Phong, and Dang Kieu Nhan

This gives an interesting account of the social and economic forces that have influenced the strategies of farm households in Vietnam and describes the role of Integrated Agriculture-Aquaculture Systems in the farmers' strategies.

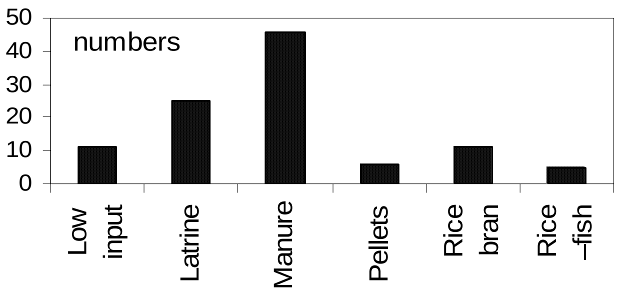
Dramatic changes in the Mekong Delta

Settlements on most of the Mekong delta are relatively recent and began mainly after the construction of the first canal -- marking the border with Cambodia -- around 1840. Settlers dug multi-purpose ponds to build a homestead high enough to avoid the yearly floods. Until 1970, next to fish, floating rice was the main cash crop produced once a year. Water buffalo provided farm power. Most farmers were already producing vegetables and fruits and raising a variety of small livestock on their homestead. The multi-purpose pond was "fed" with various types of waste from farm and household; external inputs were hardly used and the fish grew without requiring much labor. Since 1975, with the policy that put a high priority on rice production, the Vietnamese government invested in irrigation systems to promote rice intensification with 2 or 3 crops a year. This and other economic policies made Vietnam one of the world's top rice producers. But it also led to overproduction of rice (by 1986) and depressed prices (after 1990). Consequently farmers transformed rice fields to orchards with ditch-dike systems, producing fruit and fish. The state supported the changes by providing improved fruit tree varieties. Diversification was encouraged by introducing improved breeds of pig, chicken and duck. Within 20 years the buffalo has almost disappeared from the landscape, and the small family farms earning mainly cash from rice have been transformed into mixed farms producing a wide variety of products for the market.

The role of the fishpond in integrated systems

These integrated agriculture-aquaculture systems (IAAS) spread throughout Vietnam during the past 20 years notwithstanding the global trend of specialisation in agriculture. IAAS attracted our interest because mixed farming was thought to be more sustainable than mono-crop farming: farms with several components that are positively interacting would use nutrients more efficiently. Most farmers in the delta use the fish pond to recycle various kinds of waste (Figure 1). The nutrients are recycled when the water is used for irrigation and when the pond mud is applied to base of the trees that are planted on the dikes.

Figure 1: Main feed resources of fish production systems practised in the Mekong delta (adapted from Bosma *et al*, 2006. Netherlands Journal of Agricultural Science 53-3/4 281-30**0.).**



Why farmers practise integrated systems

This improved national rice security (but lower returns to farmers from their rice crop) had the effect of pushing farmers to take risks by engaging in activities in which they had less know-how. A compelling motivation was their desire to improve livelihood and diet quality of the family members. When a new household is being established, the family would give more importance to non-agriculture diversification or finding livelihood or employment in the non-farm sector. At the onset of family expansion, when the first baby is born, the new mother would usually switch from off-farm to homebound activities such as raising pigs or fish. During the household expansion phase, when more children are added to the family, farmers tend to increase the virtual farm size by raising a larger number and variety of livestock. The choice of the component is motivated by the access to know-how, market opportunities, and natural, physical and financial asset availability. Younger farmers with a small farm area may prefer, for instance, labor-intensive hatcheries or fingerling grow-out to earn more income. In the accumulation phase, when the family begins to acquire capital and social assets, the farmers would invest in land or formal education for their children. During consolidation, households with no successor (the children find work elsewhere rather than take up farming) often turn to fattening fish instead of growing rice to reduce labor input.

Benefits of integrated systems

IAAS allow the household to make seasonal adjustments according to market opportunities. The parts of the farm enterprises as well as labor allocation that are easy to change or re-allocate are the livestock components, the intensity of the fish production, on-farm family labor input, and off- and non-farm income generation. The way on-farm family labor is used, the opportunities for off-and non-farm income, and the gross returns from the farm significantly affect a household's income. How much it earns is the result of on-farm family labor, and the off- and non-farm income together with the farm gross margins.

The farm gross margin is determined by the land use intensity of rice, fruit trees, cash crops and fish, access to market, and income from off-farm and non-farm labor. Changes in recent years indicate a trend from extensive farming toward diversification and intensification. Farmers invest more time and capital in some of the existing components. Effective integration of the components and the number of components contributing to cash income improved the cash income from farm activities. Farms with more farm components and more components contributing to cash income earned, on average, almost 50% higher income. In general, farms with at least three components contributing to cash income did better.

A future for integrated systems

The effective integration of components is hampered by the small size of homesteads, the distance between the homestead and the fields, and a small total farm area. The poorest are likely to diversify outside agriculture as they lack resources for on-farm diversification or intensification. Improved infrastructure and technologies, urbanisation, and industrialisation have contributed to higher cost of land and labor. This offers an opportunity for the poor to leave agriculture and seek employment in the industrial, commercial or service sectors. An increasing number of older households do not have a successor as their children find jobs outside agriculture. Such changes will make land available to those that stay in farming and increase farm sizes. Land exchange programs could then follow.

Although the average farm size was around 1 ha, small farmers in the delta have access to the global market. The export of rice, pigs, fruits and fish is organised through a network of middlemen. But policy makers often suggest that the quantities produced by small farmers do not allow the organisation of efficient industries and market chains. On the other hand, the organic food chain for palm-oil, coffee, and tea shows that small farmers can be successfully integrated in the global market. While transaction costs are lower for the industry and traders if they deal with large producers, organized small farmers doing organized marketing would enable them to attain economies of scale as well as provide the same advantage of a lower transaction cost to traders. Organized marketing could even enable them to access markets directly so that they capture much of the benefit from trade. Scientists and policy-makers need to consider these when making recommendations.

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About the STREAM Journal

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Purpose

The *STREAM Journal* is published quarterly to promote participation, communication and policies that support the livelihoods of poor aquatic resources users in Asia-Pacific, and to build links within the aquatic resources management and other sectors across the region. The *STREAM Journal* covers issues related to people whose livelihoods involve aquatic resources management, especially people with limited resources, and government, non-governmental and international practitioners who work with them in communities. Such issues include learning, conflict management, information and communications technologies, aquatic resources management, legislation, livelihoods, gender, participation, stakeholders, policy and communications.

Another equally important purpose of the *STREAM Journal* is to provide an opportunity for seldom-raised voices to be heard and represented in a professional publication that is practical yet somewhat academic. The contents of the *STREAM Journal* should not be taken as reflecting the views of any particular organization or agency, but as statements by individuals based on their own experience. While authors are responsible for the contents of their articles, STREAM recognizes and takes responsibility for any editorial bias and oversights.

Distribution

The *STREAM Journal* is available in two formats:

- An electronic PDF version which is distributed through the STREAM Communications Hubs in each country
- A version which can be accessed and downloaded in PDF format from the Virtual Library on the STREAM Website at www.enaca.org/stream or www.streaminitiative.org

Contribution

The *STREAM Journal* encourages the contribution of articles of interest to aquatic resources users and people who work with them. The *STREAM Journal* also supports community-level colleagues to document their own experiences in these pages.

Articles should be written in plain English and no more than 1,000 words long (about two A4 pages of single-spaced text).

Contributions can be submitted to Pedro B. Bueno at <pedro.bueno@enaca.org >.

About STREAM

Support to Regional Aquatic Resources Management (STREAM) is an Initiative designed within the five-year Work Program cycle of the Network of Aquaculture Centres in Asia-Pacific (NACA). It aims to support agencies and institutions to:

- Utilize existing and emerging information more effectively
- Better understand poor people's livelihoods, and
- Enable poor people to exert greater influence over policies and processes that impact on their lives.

STREAM will do this by supporting the development of policies and processes of mediating institutions, and building capacity to:

- Identify aquatic resources management issues impacting on the livelihoods of poor people
- Monitor and evaluate different management approaches
- Extend information, and
- Network within and between sectors and countries.

The STREAM Initiative is based around partnerships, involving at the outset a coalition of founding partners (AusAID, DFID, FAO and VSO) supporting NACA. It has adopted an inclusive approach, reaching out to link stakeholders engaged in aquatic resources management and supporting them to influence the Initiative's design, implementation and management.

The partnerships’ work is coordinated in each Country Office through a National Coordinator (a senior national colleague agreed with the government) and a Communications Hub Manager (a full-time national colleague supported in the first two years by STREAM), and linking a range of national stakeholders. The Communications Hub is provided with hardware, software, training, information-technology support, and networking and human resources support, and links national stakeholders through an internet-based virtual regional network.

National coordination is guided by an annually-reviewed Country Strategy Paper (CSP) drawn up by the Coordinator and Hub Manager in consultation with stakeholders with whom they regularly network. A CSP identifies key issues, highlights regional linkages, proposes and prioritizes key actions, and seeks funding for these from STREAM and elsewhere (with STREAM support).

The NACA Secretariat in Bangkok directs the Initiative, provides a regional coordination function, and funds and manages cross-cutting activities dealing with livelihoods, institutions, policy development and communications, the four outcomes-based STREAM themes.

STREAM implementation is an iterative process, initially operating in Cambodia, India, Indonesia, Lao PDR, Myanmar, Nepal, Pakistan, Philippines, Sri Lanka, Vietnam and Yunnan, China, and expanding within Asia-Pacific where opportunities exist to tackle poverty and promote good governance, as experience is gained, lessons are learned, impact is demonstrated and additional funding is secured. STREAM’s communications strategy aims to increase impact by ensuring that existing knowledge and expertise inform ongoing change processes around the region, and that the lessons learned are disseminated throughout Asia-Pacific. The *STREAM Journal* and the STREAM website are components of this strategy.