Aquaculture and Sustainability through Integrated Resources Management*

Clive Lightfoot, Mary Ann P. Bimbao, Jens Peter T. Dalsgaard and Roger S.V. Pullin

International Center for Living Aquatic Resources Management, MCPO Box 2631, 0718 Makati, Metro Manila, Philippines

Aquaculture in developing countries can improve the sustainability of small-scale farms provided that it is fully integrated with other enterprises and household activities so as to allow farm families and communities to manage their natural resources effectively. This requires the consideration of pond management and fish husbandry as means to a variety of ends (water storage, soil conservation and fertility, integrated pest management, etc.), not just production of fish. This paper discusses the evolution of this broad Integrated Resources Management (IRM) approach, principally with reference to the Inland Aquatic Resources Systems Program of ICLARM, and gives some examples of relevant activities in tropical developing countries, research methods and future challenges.

The authors are scientists at the International Center for Living Aquatic Resources Management (ICLARM), Philippines. Clive Lightfoot heads the Integrated Resources Management Group of which Mary Ann Bimbao and Jens Peter Dalsgaard are members as economist and ecologist, respectively. The group is part of ICLARM's Inland Aquatic Resources Systems Program, directed by Roger Pullin.

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Integrated farming systems, with aquaculture as a major or minor component of crop- and livestock-based farms, differ greatly from extensive or intensive fish farms that are stand-alone enterprises. Stand-alone fish farms can be risky ventures, especially for resource-poor farmers in developing countries, because of their environmental effects, e.g. pollution, and economic factors, such as the price volatility of some aquatic produce, especially exports. Such ventures have resulted in environmental and financial disasters in Africa and Asia (Cross, 1991; McClellan, 1991; Polk, 1991). On balance, successes included, intensive aquaculture has done little to reduce poverty and malnutrition.

Integrated farming systems that include semi-intensive aquaculture are less risky because of their efficiency, derived from synergisms among enterprises, their diversity of produce and their environmental soundness. On this basis, integrated systems became widely hailed as a panacea for aquaculture development to benefit small-scale farmers in developing countries. This lasted but 10 short years (McClellan, 1991). The various combinations of fish with livestock and crops, designed by scientists, often performed impressively on research stations (e.g. Edwards, 1983; Hopkins and Cruz, 1982), but on-farm performance was mixed. Moreover, the success of rice-fish (small fish in rice floodwaters), pig-, chicken- or duck-fish systems, publicized in aquaculture texts, was usually evaluated solely on the production and profitability of fish or other aquatic produce. Making such systems work towards only these objectives can escalate costs beyond the means of small-scale farmers.

Small-scale farmers have a risk-averse attitude towards investments in new ventures like aquaculture. They like to see risks spread among benefits to other farm enterprises and household needs, such as secure water supplies. In order for aquaculture to be integrated at this level of complexity, farmers must participate in system design. In addition, fish production-orientated scientists will have to widen their perspectives. At present, however, a narrow view that small-scale, relatively intensive fish production should be the sole or primary goal of integrated agriculture-aquaculture systems is still embraced by many researchers, advisers and extensionists (Coche, 1991).

Wider perspectives

Farmers are not docile accepters of technologies. They possess large stocks of indigenous knowledge that include methods to adapt and to generate technologies (Lightfoot, 1987; Richards, 1985; Warren, 1991). Over the last few years, much progress has been made in formalizing the participation of farmers in agricultural research (Chambers *et al.*,

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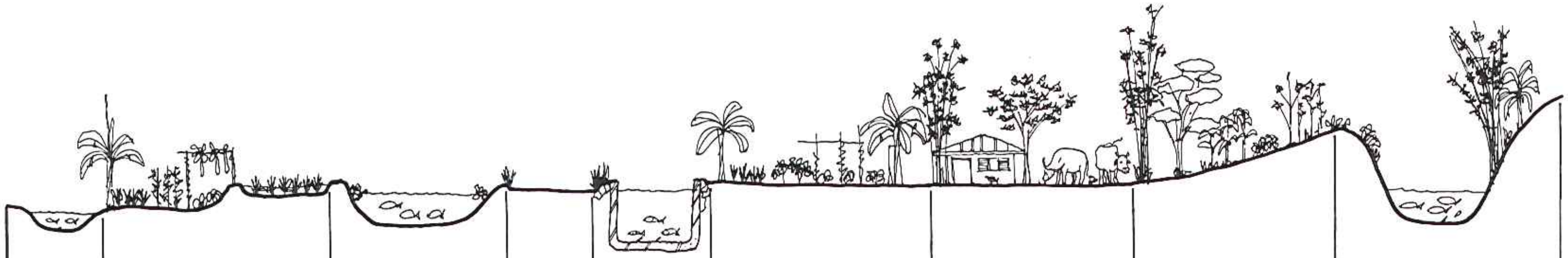

Resource system	Stream [Sapa]	Lowlying lowland [Salogan]	Fishpond [Palaisdaan]	Road	Irrigation canal	Lowland [Tubigan]	Homestead [Bahayan]	Upland [Kataasan]	Rivers and banks [Ilog at bangbang]
Soil type		Red and white clays	Red and white clays		Rocky	Red loam	Red loam	Red loam	
Water source		Gravity irrigation and rainfall	Gravity irrigation and rainfall		Prinsa River	Gravity irrigation and rainfall	Rainfall	Rainfall, and gravity and manual irrigation	
Crops and vegetables		Rice, azolla, chili pepper, bell pepper, peanut, cabbage, spongegourd, wingbean, stringbean, ladyfinger	Water spinach			Rice, whitegourd, bittergourd, chili pepper, bell pepper, peanut, onion, bittergourd, stringbean, watermelon, squash, cabbage, spongegourd, eggplant, maize		Rice, maize, sweet potato, cassava	
Trees		Bamboo, banana, gliricidia				Banana, gliricidia	Neem, gliricidia, leucaena, bamboo, tamarind, papaya, banana, mango, guava, jackfruit, pomelo, lemon, blackberry	Gliricidia, bamboo, starapple, guava, soursop, mango	Bamboo, banana, leucaena, gliricidia
Forage grasses				Napier, imperata		Napier, imperata		Napier, imperata	Napier, imperata
Animals	Golden snail, snail, shrimp, tilapia, carp, catfish, clam	Tilapia (rice-fish)	Golden snail, snail, clam, shrimp, tilapia		Golden snail, snail, shrimp, tilapia, carp, catfish, clam	Golden snail	Pig, goat, cattle, water buffalo, duck, chicken, eel	Golden snail, water buffalo, goat, cattle	Golden snail, snail, shrimp, tilapia, carp, catfish, clam

Figure 1 Village transect from the Philippines.

A Malaŵian woman draws a bioresource flow model of her farm.

1989; Haverkort *et al.*, 1991; Hiemstra *et al.*, 1992). Similarly, our view is that aquaculture must go beyond fish production and cash income to evaluating the many social, cultural and ecological services that pond water and pond biota, including farmed fish, can perform on an integrated farm that has some aquaculture, however minor that aquatic enterprise may be. This view goes beyond aquaculture as an enterprise to aquaculture and water management as an engine that can drive sustainability for the entire farming system (Lightfoot, 1990; Lightfoot and Pullin, 1991).

The Technical Advisory Committee (TAC) of the Consultative Group on International Agricultural Research (CGIAR) has argued that "sustainable agriculture should involve the successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources" (TAC/CGIAR, 1989). Pullin (1993) commented that the sustainability of systems is best considered with reference to their "evolvability" or scope for future change. The TAC/CGIAR statement encompasses some awareness of the

A Malaŵian integrated farm of rice, vegetables and fish in stark contrast with its desertified surroundings.

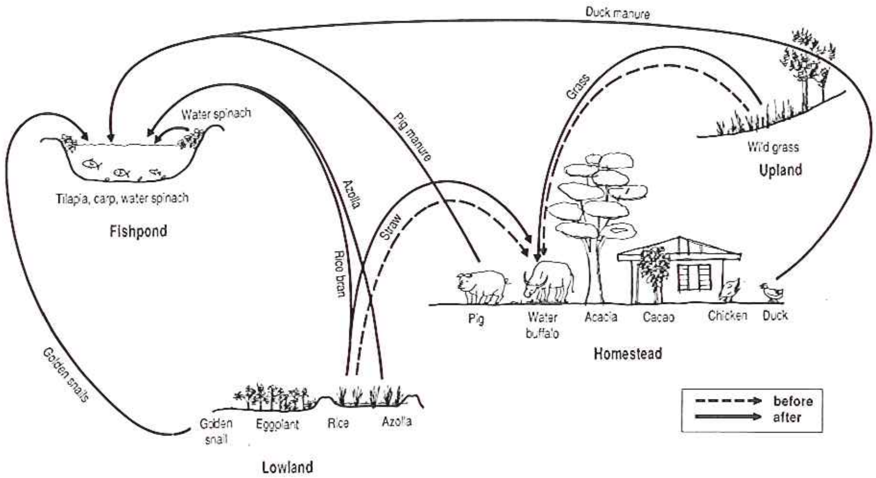

Figure 2 Before and after integration: bioresource flows between resource systems, Philippines.

importance of the evolvability of farming systems, but only in terms of capacity to respond to human demands, e.g. market forces, public opinion, laws, etc. However, systems must also have the capacity to adapt to biological and climatic changes. Altieri (1989) holds that sustainability can only be approached when farmers manage their natural resources ecologically. It is therefore likely that degradation of resources (soil, water, aquatic biodiversity of food and other organisms necessary for a healthy environment for farmed fish) will constrain the evolvability of integrated agriculture-aquaculture.

To counteract this, we recommend a broad view of integrated farming, encompassing a fully integrated management of all the natural resources available to farm households. To emphasize this broad scope, we prefer the term Integrated Resources Management (IRM) to Integrated Farming Systems. We recognize that aquaculture, even if small-scale and low yielding in terms of aquatic produce, still has an integral and sometimes pivotal role in IRM.

An integrated resources management approach

The IRM approach integrates the management of new enterprises, particularly aquaculture, with those of the existing farming system and with their respective natural resource systems so that opportunities for rehabilitation and synergism can be exploited. The utilization of the economic, social, nutritional and ecological services offered by managed water resources and fish is seen as a basis for sustainable farming systems. Thus, households are encouraged to see farm enterprises (particularly aquaculture) as mechanisms to improve natural resources management and overall farm system performance. The approach involves interdisciplinary research in close partnership with the targetted resource-poor farmers. Indeed, the use of indigenous categories of natural resource systems as entry points for research builds a common foundation for farmers and researchers.

Natural resources management and rehabilitation, and farmer-participatory skill-building, have shaped ICLARM's research agenda in an attempt to find procedures that will be used by farmers to help them make their own decisions and conduct their own experiments on how to integrate aquaculture and use their resources in a more sustainable way (Lightfoot *et al.*, 1993).

The Participatory Research Appraisal method that we have developed uses household groups to identify and map indigenous categories of natural resource systems. Village transects (Figure 1) summarize this information in a format easily appreciated by community members, extensionists and researchers alike.

These diagrams serve as foci for the additional detailed development of individual farm bioresource flow models. The bioresource flow models become the centre for sharing information and

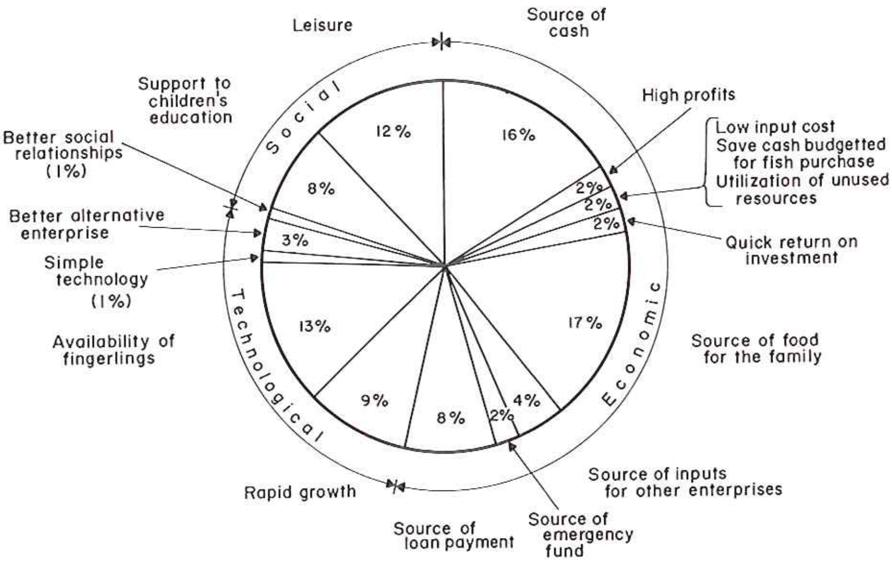

Figure 3 Encouragement factors for utilization of seasonal ponds and ditches, Bangladesh. (Source: Gupta, 1992)

experiences and brainstorming ideas on how to rehabilitate natural resource systems and integrate new enterprises, such as aquaculture, agroforestry and vegetable gardening, into existing farming systems.

Models of before and after integration scenarios (Figure 2) convey clear pictures of the impact of new technology adoption and integration. They help farmers and outsiders to appreciate the importance of shifting the boundaries and focus from the individual enterprise to the entire natural resource system used, as well as the benefits to be realized from managing resources in a complementary and integrated manner that makes efficient use of available biological materials.

Over the last two years, farmers have participated in these procedures in ICLARM projects in Bangladesh, Ghana, Malaŵi and the Philippines (ICLARM, 1992). The impact of this work on farm households, farm ecology and the environment is illustrated here through four examples.

Trees, forage and vegetables surround a fishpond in Ghana.

Impact

Bangladesh

ICLARM's collaborative project with the Bangladesh Agricultural Research Council (BARC), the Fisheries Research Institute (FRI) and the Department of Fisheries (DOF) has assisted the development of technologies for sustainable aquaculture that are consonant with the resources of the rural households and existing farming systems. The technologies enable short-cycle aquaculture, using fish species such as silver barb (*Puntius gonionotus*) and Nile tilapia (*Oreochromis niloticus*) in seasonal (4–6 months), small (100–200 m²) waterbodies, integrated into the existing agricultural production system (Ahmed, 1992; Gupta, 1992; Lightfoot *et al.*, 1992).

Farmers have expressed satisfaction with the integration of aquaculture and other farm enterprises (Figure 3) and plan to continue and expand these operations (Gupta *et al.*, 1992). Their reasons for doing so are far more diverse and complex than money or food. Leisure and social relationships drive adoption of the system by households, as do provision of inputs for other enterprises and rapid growth of fish for quick returns. Farmers can produce fish for a fraction of the market price: US$0.12–0.30 kg^{-1} compared to US$0.81–1.16 kg^{-1} Some farmers with seasonal ditches as small as 170 m² can raise 25–30 kg of fish in the 4–6 months that the water is available. A pond of about 300 m² can provide a family of six with the present annual fish consumption level of 7.9 kg caput^{-1}.

This work is now helping NGOs, such as the Bangladesh Rural Advancement Committee (BRAC) and Proshika, to assist more than 30,000 fish farmers, of whom nearly 60% are women, in utilizing formerly derelict seasonal ponds and ditches. The adoption by women of integrated aquaculture not only empowers rural women, but also improves the nutrition of their families (Gupta, 1990). A 98% recovery rate on credit proves its success.

Ghana

Over the last two years, in cooperation with the Institute of Aquatic Biology (IAB) and a local NGO - the Ghana Rural Reconstruction Movement (GhRRM), a group of farmers in the Mampong Valley, Eastern Region, Ghana, drew bioresource flow models of future integrated farming systems. Their plans to rehabilitate water resources for dry season vegetable gardening and aquaculture are now being realized (Ofori *et al.*, 1993).

In order to assess the potential impact of integration on the nutrition of households, bioeconomic models were constructed. The model used a rural household of five persons to compute the annual demand for main nutritional components. The annual nutritional supply to such a household was calculated for a holding size of one hectare of which 40% was under fallow and the rest cultivated. Crop yields were based on data from the Ministry of Agriculture. Nutritional inputs to the diet from staples, vegetables and condiments, freshwater and marine fish and meat were considered using data from various sources (Ruddle, 1993a). Integration added the outputs of a fishpond of 100 m² and a vegetable plot of 400 m². The models suggest that integration can improve household nutrition as well as cash income (Ruddle, 1993b). The most significant nutritional impact from integration is the boost in protein intake from around 60% of recommended

Table 1 Before and after impacts of integrated aquaculture, Malaŵi.

Before	After
Marginal wetland unutilized	Marginal land brought into productive use
No integration between resource systems or farm enterprises	Ponds serve as a focal point for direct or indirect links between resource systems
Crop residues not recycled	Crop residues such as maize bran and green leaf waste used as pond input
Water shortage for vegetable garden in late dry season	Ponds placed adjacent to gardens provide water for irrigating vegetables Average dimba (vegetable garden) earnings increased from US$82 to US$112/year
Households reliant on uncertain water supplies	Households use pond as water catchment for domestic use and watering livestock
Reliant on fertilizer for vegetable garden or overutilize exhausted soils	Use pond as processing unit for converting low quality crop waste into fertile mud for transfer to garden; reduced fertilizer use
Buy fish; rarely eat fish	Ready supply of fish for household consumption; rarely buy fish Average fish harvest values: US$22 (1 harvest), US$45 (2 harvests)
Marginal wetland does not provide food and income for household	Conversion to ponds provides food and income (Average income from integrated rice-fish=US$76/year)
Rice either not grown or only one crop per year	Rice-fish ponds provide two crops of rice per year; rice grown for first time
Average annual income before integration (1990)=US$155	Average annual income after integration (1992)=US$235 A year that saw a nationwide drought and a currency devaluation of 20%

Source: Adapted from Lightfoot and Noble (1992).

levels to over 120% (Figure 4). Other significant impacts result from vegetable contributions of vitamin A (66%) and vitamin C (57%).

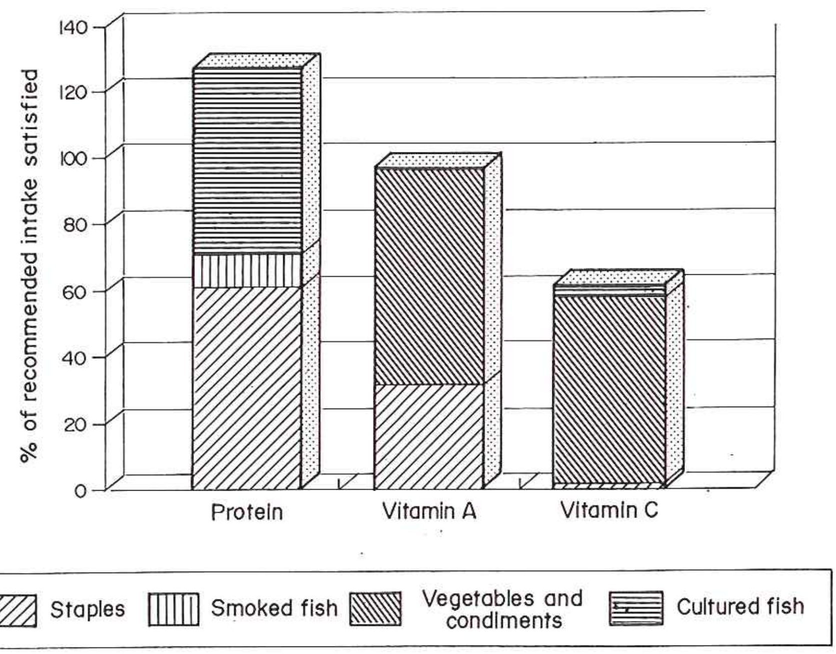

Figure 4 Impact of integration on farm household nutrition for protein, vitamin A and vitamin C, Ghana. (Source: Adapted from Ruddle, 1993b)

Malaŵi

In Zomba District, Malaŵi, a joint ICLARM–GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit) research program with the Fisheries Department has assessed the impact of integrated aquaculture-agriculture development on smallholder farming systems (Lightfoot and Noble, 1992; Noble and Costa-Pierce, 1992; Noble and Rashidi, 1990).

Initial results from five farmers, who are part of a group of some 30 farmers new to integrated farming, indicate that adoption has had significant and diverse impacts on farm management and the performance of farming systems (Table 1). In every case, the presence of ponds has resulted in resource linkages through recycling of farm residues and thus more efficient and economical use of available natural resources. This includes the wise use of wetland areas. Rice-fish pond contributions alone to gross farm incomes varied from 10 to 62%. Additional contributions can be expected as farmers' skills increase. The fact that these households managed to stabilize if not slightly increase food and cash in a year of drought and devaluation is a remarkable feat in itself.

The implications of these changes are likewise diverse. The signs of positive impact encourage further work. Farmers demonstrate ability to build up and improve quickly their skills in natural resources management. Through participatory efforts they gain confidence in their own knowledge and abilities. Thus, introducing the management of water and living aquatic resources provides an entry point towards more sustainable farming. Farmers and scientists alike recognize that more sustainable farming can also mean more productive and profitable farming.

Philippines

In order to assess the impacts of changes in natural resource management, data were collected *via* direct monitoring and from recall from seven households in Nuigan, Cavite Province, Philippines. All farmers were established cooperators of the International Institute of Rural Reconstruction (IIRR). These data were in turn used to calculate four simple indicators of sustainability for each farm: economic efficiency (net income in US$), resource system capacity (biomass output in tonnes ha^{-1}), species diversity (number of cultured

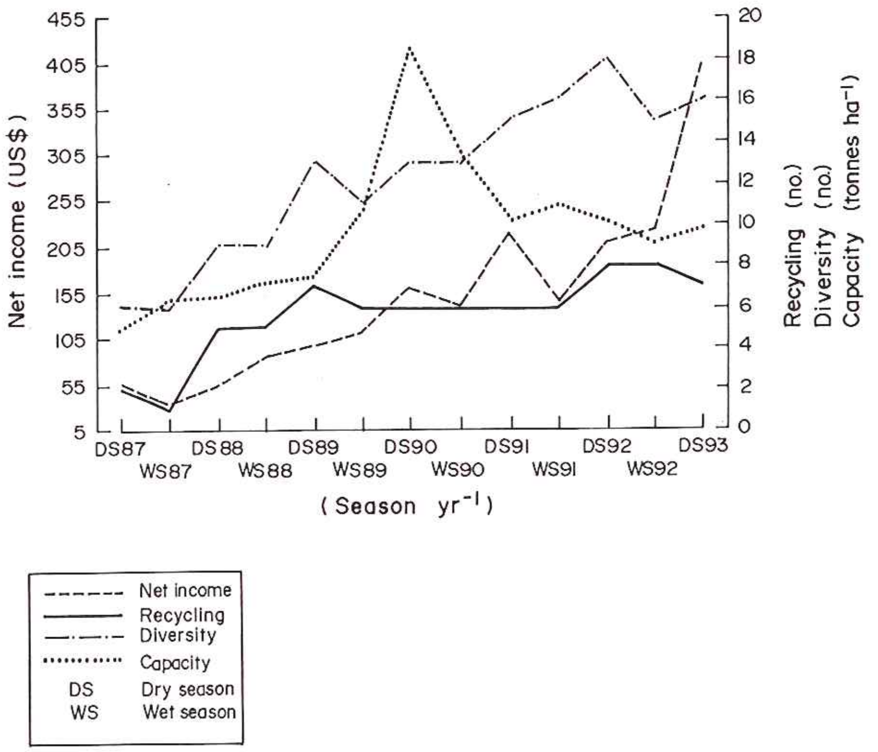

Figure 5 Time series performance indicators by season, Philippines.

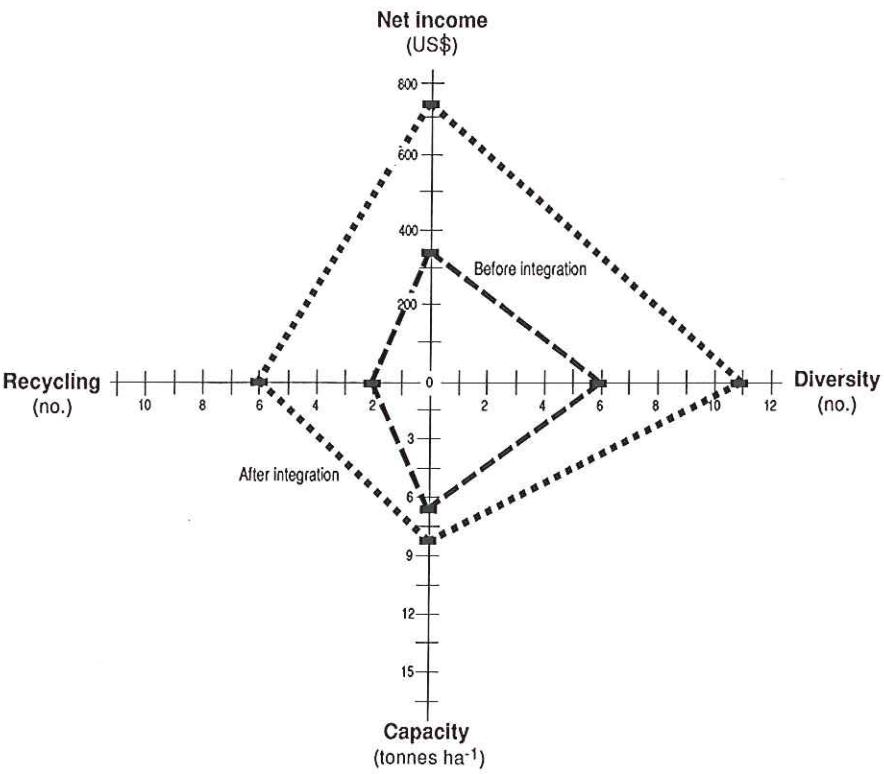

Figure 6 Farming systems performance indicator kites before and after integration, Philippines.

and utilized species) and bioresource recycling (number of bioresource flows). By plotting the indicators in time series graphs (Figure 5) new information was revealed on the evolvability of the farming systems over time. One can appreciate visually what impacts management changes and technology adoptions have had and how system performance is developing positively or negatively.

The individual indicators show a pattern of dynamism within years due to seasonal differences and climatic change. The general trend though shows a gradual and steady improvement in overall farm performance with the advent and integration of aquaculture. Greater water availability allows for improved water use not only for fish and aquatic plants but also for rice and vegetables.

Enterprises and natural resource systems thus support each other *via* improved water resource use and bioresource management manifesting itself in a simultaneous increase in all indicators. In order to compare discrete before and after integration scenarios, snapshots from the time series graphs are taken and plotted in kite diagrams (Figure 6). These provide at-a-glance information on performance and are useful for comparing systems across time and space, e.g. before and after integration: the larger the kite the better the performance.

Future challenges

At this time, our experience suggests that this IRM approach is promising. We see small but growing numbers of new entrant farmers beginning to adopt IRM. We see rehabilitation of aquatic resource systems to benefit many enterprises. We see rapid transformation of farming systems to more sustainable systems. But there is much that we do not see and do not know.

Farming systems can be transformed rapidly – our monitoring of sustainability indicators shows this – but are these indicators the right ones or the only ones? The simplistic counts of flows and species should take account of quantity as well. More direct determinants of the quality of natural resource systems need to be found. Perhaps indigenous categories will help here.

Indicators for equity, particularly gender equity, and ecosystem attributes such as resilience and maturity are also needed. The use of ecological modelling tools like ECOPATH could provide important inputs here (Christensen and Pauly, 1992).

Just as important as improving these indicators is improving our valuation of the ecological services of IRM. Whereas cash substitutions for inorganic fertilizer and chemical sprays can be calculated, values for natural resource system rehabilitation, species diversity and bioresource flows are much harder to determine. Farmers in Vietnam have reported that fish in ricefields enable them to reduce fertilizer inputs by 28% (Lightfoot and Tuan, 1990). Similarly, farmers in the Philippines report that fish saved US\$12 ha^{-1} on herbicides and US\$13 ha^{-1} on pesticides (Fermin, 1992).

New entrants are evolving IRM systems and sharing their knowledge and experiences with others. This, however, does not mean that some do not drop out. Some never start. We do not know the reasons for this behaviour, but current farm and land tenure policies probably explain some of it. Policy instruments that promote IRM need to be formulated and policy disincentives need to be dismantled. Using policy to guide the evolution of IRM systems will become especially important to avoid the dangers of success. Techniques and technologies that so obviously assist the resource-poor, particularly women, are bound to equity issues both within a household and in the community at large. Successful exploitation of underutilized natural resource systems are bound to attract more users than they can carry. Avoiding these problems and those of earlier attempts at aquaculture in integrated farming will require the wholehearted participation of the community in IRM.

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