International Journal of Ecology and Environmental Sciences 32(1): 3-14, 2006
© INTERNATIONAL SCIENTIFIC PUBLICATIONS, NEW DELHI

Integrating Agriculture, Fisheries and Ecosystem Conservation: Win-win Solutions

V. V. SUGUNAN[#], M. PREIN[*] AND M. M. DEY[*]
WorldFish Center Regional Center for Africa and West Asia, Abu El Feda Street, Zamalek, Cairo 11211, Egypt
[*]*WorldFish Center, Jalan Batu Maung, Batu Maung, 11960 Bayan Lepas, Penang, Malaysia*
[#] Corresponding author; *Email: vsugunan@worldfish-eg.org*

ABSTRACT

Integrated Agriculture-Aquaculture (IAA) is essentially diversification of agriculture, leading to synergisms among sub-systems resulting in a higher productivity from land/water area under the farmers' control. One method of achieving this is adding a pond culture component to a farm system, basically to receive and utilize the nutrient inputs from the latter. The second method is physically integrating aquaculture into the other systems by modifying the farm design and operations. More than 30% of the total geographical area in 40 countries covering 9.2 million km^2 in Sub-Saharan Africa is suitable for some form of integrated aquaculture. Based on the present production level, it has been projected that 35% of the Africa's increased requirement of fish in 2010 could be met by small scale fish farmers using IAA in just 0.5 % of the total potentially available area.

The main motivations that enable farmers in adopting IAA are to i) reduce risk from cropping, ii) accumulate capital iii) provide draught animal power and manure for fertilizer/fuel (in case of livestock), iv) satisfy cultural needs, v) enhance prestige/status vi) provide food, and vii) generate income. An opportunity for further increased production in the flood-prone ecosystem is the integration of capture fisheries and fish culture with rice farming on a community management basis. However, a key requirement for win-win situation is the development and operation of a good governance system based on community approach in managing the IAA operations. This helps to ensure equity, minimize conflicts among stakeholders and ensure easy resolution of conflicts, should they arise. This has been shown to work very well in a floodplain rice-fish culture system, where in spite of individual ownership of rice plots, fish culture is done on a community basis. Rice-fish systems foster ecological conservation through a number of means such as use of natural organic inputs, least alteration in the physical habitat, safeguarding agro-biodiversity (both rice and fish), allowing free movement of wild stock (in flooded systems), efficient recycling of farm wastes, utilizing all possible synergisms in various farm sub-systems, encouraging community and participatory approach in managing the resources, which can facilitate mass awareness on conservation.

Key Words: Agro-biodiversity, Floodplain, Rice-Fish Culture, Deepwater Rice, Sub-Saharan Africa, Wetlands,

INTRODUCTION

Integration of fish culture with other agricultural practices, aimed at reducing input cost and optimizing resource use, has been in vogue from time immemorial in many parts of the world. For 2000 years or more, Chinese farmers have been taking advantage of this synergy among fish culture, agriculture and animal farming, where the outputs from one system can be utilized as input for another, ensuring efficient waste recycling and optimum use of resources. Other Asian countries like, Bangladesh, India, Malaysia, Indonesia Thailand and Vietnam also have a long history of integrated agriculture systems, covering a wide range of activities, especially those involving rice, fish and livestock. The concept of integrated culture systems is relatively new in Africa, but farmers in many countries of the continent now take a very keen interest in it due to the obvious advantages. Over the years, the practice has been refined, modified, diversified and adapted by the enterprising farmers in many parts of the world to meet their location-specific and resource-specific needs and requirements. In the process, the system has acquired certain social, economic and environmental dimensions. Today, this farming system is fast becoming a favorite option among the resource-poor fish farmers in the developing world, mainly because of its ability to remove many risks associated with the stand-alone pond aquaculture of both intensive and extensive scale (Prein 2002).

In addition to the apparent benefit of reducing input cost, such integration has many social and environmental advantages. The expected increase in expansion of this practice into the peri-urban areas, with increased linkages between different farms and specialized agro-industries adds a new relevance to it from a human livelihood perspective (Edwards 1998). Intensive aquaculture, which often focuses on high value species, operates at high energy and nutrient levels, often earning its ill-repute as a polluting industry that causes negative impacts on the aquatic ecosystems through nutrient loading, salinity changes and contamination from chemicals and antibiotics. Operating on a lower scale and depending heavily on organic inputs from the component sub-systems, integrated agriculture-aquaculture (IAA) is more acceptable from environmental and sustainability angles. One of the most important positive attributes of the system is its ability to integrate into very small, improvised and household enterprises at very low scales of operations, and thereby gaining its social and economic relevance among the rural poor. Viability of the system in such conditions has already been demonstrated in many developing countries in Asia and Africa.

In spite of its unmistakable role in augmenting farm productivity and enhancing the social and economic status of the rural poor, there are no reliable estimates on the current and potential production from this resource, mainly due to highly diffused nature of this activity, operated in a wide range of scales starting from simple, instinctive re-use of farm wastes to highly knowledge-based systems, practiced in specially designed farms. Most of the freshwater fish cultured in China comes from small fish ponds (*c.* 1 ha) integrated with crop and livestock production (Chen et al. 1995, Mathias et al. 1998). Given that China is the biggest inland fish producing country in the world, which accounts for 71% of the total global aquaculture production, the total quantity of fish that emanates from IAA can be considered as very substantial.

Definition

Integrated agriculture-aquaculture (IAA) is essentially diversification of agriculture, leading to synergisms among sub-systems resulting in a higher productivity from land/water area under the farmers' control. However, viewed from a wider perspective, it can be seen as a part of integrated resource management (Lightfoot et al. 1993). Prein (2002) defines IAA as concurrent or sequential linkages between two or more human activity systems (one or more of which is aquaculture), directly on-site, or indirectly through off-site needs and opportunities. This linkage is not limited to various agriculture-related activities to exchange mutual benefits among various crops, but extends to other human activities such as sanitation (nightsoil, septage and other forms of human excreta re-use), nutrient recovery (hydroponics-fish, breweries) and energy recovery (culture in heated effluents of power plants, dairies etc), making IAA ecologically sensible and environmentally sustainable.

Types of Integrated Farming Systems

Integration of agriculture with aquaculture is achieved in two ways. One way is adding a pond culture component to a farm system, basically to receive and utilize the nutrient inputs from the latter. The second method is physically integrating aquaculture into the other systems by modifying the farm design and operations (Figure 1). Both the systems can be operated over the entire spectrum of scales ranging from small to large-scale enterprises that are fully market-oriented. In the first category of IAA, ponds receive nutrient inputs from both plant- or animal-based enterprises in order to be productive and cost effective.

Ponds Receiving Nutrients

Aquaculture ponds can be enriched by a variety of inputs derived from plants and animals which act as feed or pond manure. Plant-based sources of pond inputs are usually aquatic or terrestrial macrophytes (Edwards 1998), which are planted for use as direct fish feed or as pond fertilizers. There are also grass-fed fishponds in China and Thailand (IIRR and ICLARM 1992) which use off-farm grass to feed herbivorous fishes, mainly the grass carp. Unused, decomposed grass in the pond and poorly digested grass in the fish excreta also enhance pond fertility. Other major sources of plant-based nutrients are the on-farm plants and crop residues in fishponds. Among animal-based inputs, manure and offal are the most important, which can be of livestock or non-livestock origin. Combination of aquaculture and mulberry trees previously practiced in

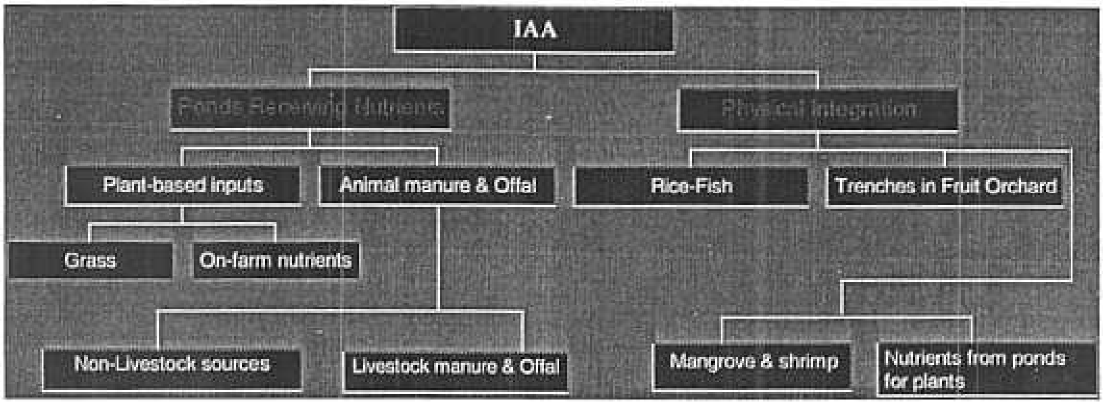

Figure 1. Different kinds of Integrated Agriculture-Aqua-culture systems

China is a typical non-livestock source of nutrients. Here, the silkworm droppings and waste pupae are fed into fishponds. Use of human night soil, sewage and septage as pond manure is another example. Manure of livestock origin such as poultry and cattle manure, pig dung, urine of pigs and cattle are very effectively used to fertilize ponds and feed fishes. Slaughterhouse wastes are good for feeding carnivorous fishes like catfishes.

Physical Integration of Aquaculture into Other Systems

Often integrated farms are specially designed to operate two or more diverse crops/animals on a complementary basis to take full advantage of farm space and inputs. Rice-fish culture is the most common IAA of this category and this is practiced in some form or other in most of the Asian countries. Rice, the commonest staple food of the developing world in general and tropical Asia in particular, is cultivated in a variety of agro-ecosystems. Recognizing it as a winning combi-nation, people living in these regions have been practicing rice-fish farming for long under a rich variety of systems adapted for different cultural, environmental and economic situations. Aside from integrating eco-logical features and services (e.g. land-water inter-actions, biological control, N-fixation), it adds value in terms of economic gains, and a number of other mutually shared benefits to ameliorate some inherent limitations of each other. Fish culture in rice-fields can be concurrent (mixed) or rotational with rice, and at different intensities. Besides sharing the habitat, they promote a variety of beneficial interactions. For example, the rice plant provides shade and food (insects and organic matter) for fish, the fish oxygenates the water and moves the nutrients thereby benefiting the rice, the fish provide biological pest control, and *Azolla* spp. fix nitrogen for the rice.

Simultaneous culture of fish and rice is known to increase rice yields, particularly on poorer soils and of unfertilized crops, probably because under these conditions the fertilization effect of fish is greatest. With savings from pesticides and earnings from fish sales, increases in net income on rice-fish farms vary considerably, but when compared to returns from rice monoculture farms, they are certainly significant with up to 100% increase.

Although fish integration can be seen in all kinds of agro-ecosystems like mountainous, irrigated, rain-fed, and flood-prone; maximum area covered under this activity is the flood-prone areas like riverine floodplains, low lying areas and wetlands. This is notwithstanding the fact that indigenous rice-fish systems using common carp *Cyprinus carpio* is known from the terraced paddy fields of mountain valleys in many countries including India and Vietnam (Demaine and Halwart 2001). In the Indian sub-continent, especially the Gangetic delta, catching fish (or culturing them) in paddy fields growing deep-water rice has been very common during flooded conditions. Many authors share the view that traditional practice of using rice field as a source of collecting natural fish stock is on decline due to many factors like floodplain modi-fications, flood control measures, use of agricultural chemicals, and other human pressure on the ecosystem. Consequently, several innovative methods have evolved by way of creating refuge for fish during low water levels, stocking fast growing species, selecting appropriate rice varieties to suit the growing time of fish, adjusting the sowing harvesting schedule, etc.

Other forms of IAA

Growing fish and prawn in trenches around fruit orchards, created while excavating the farm to raise beds for fruit trees, is a common practice in the Mekong Delta of southern Vietnam. The fish and prawn benefit from the decomposing rice straw, the fallen fruit and insects falling into water. Other examples are culture of shrimps in fenced off mangrove areas in Malaysia, Philippines and Vietnam (Johnson et al. 1999) and utilization of nutrient-rich pond sediments to fertilize crops grown on pond embankments.

Rice-Fish Culture: Resource Size and Potential

Estimates on the area available for IAA are fragmentary. China is reported to have 6.7 million ha of potential area for rice-fish culture, of which 1.67 million ha were already in use in 1997 producing 700,000 Mg of marketable aquatic animals at a yield rate of 419 kg ha^{-1} (Li 2001). Further, it was projected that the total area under rice-fish will increase to 3.3 million ha by the year 2000, which at the yield level of 1997, is equivalent to 1.4 million Mg. The price of fish is twice that of rice in China and the addition of higher value aquaculture species like crab and prawn in recent years enables the farmers to get 10–50 times higher price for aquaculture products. During the period 1995 – 97, the area under rice fish culture in Jiangsu Province of China increased from 19,606 to 68,973 ha, where prawn and crab accounted for 72.5 % of the area (Table 1). In Bangladesh, 1 million ha of deep water paddy fields are flooded annually and 40% of this is considered to be suitable for community-based fish culture during floods. Bangladesh has a potential to yield 400,000 Mg of fish from its deep-water paddy fields, against the current production of 76,000 Mg of wild fish, which are caught from the flooded area. In India, 2.5 million ha of deep water rice lands flooded to depths from 0.5 to 2.0 m for up to 6 months in an year. Similar opportunities exist in the floodplain and deltaic systems of Vietnam. In Cambodia, in the wet season, the main fishery is in rice field itself as the fish move out of the main spawning grounds. Virtually all rice-farming households in the Svay Rieng province of Cambodia regularly collect substantial quantity of fish at an average of 25 kg of fish per person per season. Rice field fishery at this time is largely open access suggesting relative abundance of fish (Demaine and Halwart 2001). Improvement in income level attributable to rice-fish integration has been reported from seven Asian countries based on some economic indicators in (Table 2).

Table 1. Yield and production of crab and prawn under rice-aquaculture in Jiangsu province, China

	Rice-crab	Rice-prawn
Total area (ha)	36,113*	13,687**
Total production (Mg)	16,245	5,712.2
Average yield of animals (kg ha)	450	412
Profit (US$ ha)	2,898	2,536

* 52.4% of the total area under rice-aquaculture

** 20.1% of the total area under rice-aquaculture

According to one estimate (Kapetsky 1995), 31% of the total geographical area in 40 countries covering 9.2 million km^2 in Sub-Saharan Africa is suitable for some form of integrated aquaculture. Based on the present production level, it is projected that 35% of the Africa's increased requirement of fish in 2010 (58,000 Mg) could be met by small scale fish farmers using only 0.5 % of the total potentially available area. Average fish productivity of integrated Malawian small holdings is 1350 kg ha^{-1} in rain-fed areas and 1650 kg ha^{-1} in spring fed areas. This is 50 to 80% more than the average production level achieved by the 48 most productive commercial fish farms in Southern Malawi i.e., about 900 kg ha^{-1} (Brummett, 2002). In Ghana, all economic indicators (gross income, total cost, net income and net cash income) increased through integration of fish pond and vegetables both for the whole farm and for the individual enterprises (Pullin and Prein 1995).

Rice Field Fishery vs. Rice-based Aquaculture

The paradigm shift, often considered in the rice-fish societies is essentially the change in accent from capturing fish from the rice field (capture) to undertaking fish culture (aquaculture/enhancement) there. Culture in the paddy field attempts to recreate the environment of rice field fishery but with stocked and cultured species. Similarly, new varieties of paddy and changed flooding regime warrant modifications in agricultural practices. This, in effect, is creation of an additional artificial environment for both rice and fish.

Table 2. Selected economic indicators of rice and rice-fish farming (from Demaine and Halwart 2001)

Indicator	Country	Change (%)	Comments
Increase in rice yield equivalent	Indonesia	+20	Research Station results, fish yield expressed in rice equivalent
Income from fish as % of total farm income	Malaysia	+7 & +9	Figures for owners and tenants respectively in double rice cropping area
Net return	Philippines	+40	Summary of results from nation-wide field trials during the late 1970s to 1987 in irrigated rice areas
Net return	China	+45	Results from four farm households in Hubei Province
Net farm income	Thailand	+18; +35	Figures from research station and farmer fields respectively
Cases with net return higher than rice monoculture	Thailand	+65	Difference in rice yield equivalents
Net benefit	Thailand	+80	20 out of 25 farms had higher net returns from rice-fish farming than from rice monoculture
Net profit	Bangladesh	+64; +95	Net benefits higher in the aman or wet season and lower in boro or dry season
Total farm cash return	Vietnam	+69	20% of the trench construction costs considered in capital costs. Operating costs increased by 83% for labor and 100% for irrigation, but had savings in the use of pesticides
	Vietnam	0	Mekong delta, beneficial and net effects thought to be related to environmental sustainability, system bio-diversity farm diversification and household nutrition

The ecological and economic impacts of these man-made alterations in the environment depend on the extent to which these modifications are effected and the intensity of operations. Some main considerations are (1) selection of rice variety, (2) selection of fish species (3), stocking rate (4), supplementary feeding and (5) use of agricultural chemicals.

Selection of Rice Variety

Commonly, the low-lying lands tend to be cultivated with late maturing varieties probably with a taller growth habit. At the extreme level of flood, farmers often cultivate floating rice, with long stems that grow with the rise of the water. However, in areas of improved water control, such variations have largely disappeared and the traditional local varieties have, in many cases, given way to higher yielding varieties of rather uniform characteristics. Use of longer-stemmed and longer maturing traditional varieties allows a higher water table and an extended period of fish farming. Although much of the expansion of rice farming in the 1980s is perceived to be associated with traditional rice farming, the case of PR China with about 1.2 million ha under modern varieties of rice, shows that the use of new rice varieties is not a constraint for rice-fish farming (Demaine and Halwart 2001).

Fish Species

At least 15 species of commercially important wild fish are known to prefer rice field habitat (*Monopterus cuchia, Rasbora daniconius, Puntius chola, Channa punctatus, C. orientalis, C. striata, Colisa fasciatus, Anabas testudineus, Amblypharyngodon mola, Corica soborna, Mastacembelus aculeatus, Mystus vittatus, Heteropneustes fossilis, Clarias batrachus*, and *Lepidocephalus* spp. (Alam and der Hoek, 2001). Although many of them are cultured in rice fields, only two (the exotic common carp, *Cyprinus carpio* and the exotic Nile tilapia, *Oreochromis niloticus*) are important fish from commercial point of view, preferred mainly due to their ecological advantage of feeding at the bottom of the food chain and thereby efficiently converting primary energy to fish flesh. Other popular species are *Barbodes gonionotus* and *Trichogaster* spp. in Thailand and Gangetic carps (*Catla catla, Cirrhinus mrigala* and *Labeo rohita*) and *P.javanicus* in India. Often local wild fish such as snakeheads *Channa striata, Clarias batrachus, H. fossilis,* or many smaller indigenous rice field species (*Puntius* spp., *Colisa facsiata, Anabas testudineus, Rasbora daniconius, A. mola,* etc) play an important role for food security and a balanced nutrition, besides being important sources of income. While farmers generally tend to exclude predatory fish from their stocked rice fields, those in northeast Thailand allow fish to enter the field although many stocked fish fall prey to wild species. This is however accepted due to high market value of wild fish at local fish markets.

Stocking and Feeding

The stocking densities followed in rice-fish farming vary widely. At a low stocking density, naturally occurring rice field organisms are readily available for fish to feed. In such low stocking rate, overall costs are lower, making this practice more suitable for resource-poor and risk-averse farmers who are at the entry-point level or still experimenting with their farming system. At higher stocking densities requiring additional fertilization and supplementary feeding, these inputs come from the farm in the form of a variety of farm products and wastes, rice bran being one important item among these. However, considering the many other uses of rice bran, it will be desirable to find an alternative so that it can be spared to other sectors or even for human use in emergencies. Farmers have the option of collecting many living aquatic organisms from rice fields and surrounding wetlands to supplement the natural food available in the rice-fish system. An example is the regular collection by hand of bigger golden apple snail (which the fish could not eat directly) by farm household family members who crush them into feed sizes.

Pest Management

One of the remarkable advantages of rice-fish farming is the ability of fish to control pests very effectively by eating them and ultimately converting them into fish flesh. Generally, integrated pest management is recommended for rice-fish farming as fish culture and rice farming are considered as complementary activities from IPM point of view. The use of pest and disease resistant varieties is encouraged minimizing the need for use of pesticide application. In rice-fish culture, the chance of pests reaching a population level to justify control action is usually low. Potential income from fish would outweigh pesticide costs. Evidence from an FAO IPM Inter-country Program in Indonesia shows that through IPM, the number of pesticide applications in rice can be reduced from 4.5 to 0.5. This not only saves cost but eliminates an important constraint in adoption of fish farming.

Floodplain Farming System and Community-based Fish Culture

Traditionally, farmers in the flood-prone ecosystem grow deepwater rice and capture fish during the rainy/flood season and subsequently cultivate a wide range of crops (such as pulses, oil seeds, vegetables) during the post flood dry season (Figure 2). In Gangetic floodplains (Bangladesh and eastern India), farmers used to get a maximum 2 Mg of traditional rice and approximately 200 kg of wild fish per ha per year with an average income of about USD 300 per ha per year. During the last few decades, with the availability of irrigation facilities, farmers started growing high yielding varieties (HYV) of rice in the dry season under irrigated conditions. The dominant farming pattern in shallow flooded areas is irrigated HYV rice during the

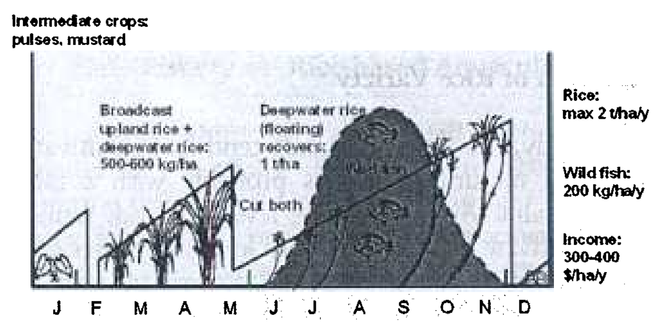

Figure 2. Evolution of farming system in floodprone areas: Best traditional system until 1970s

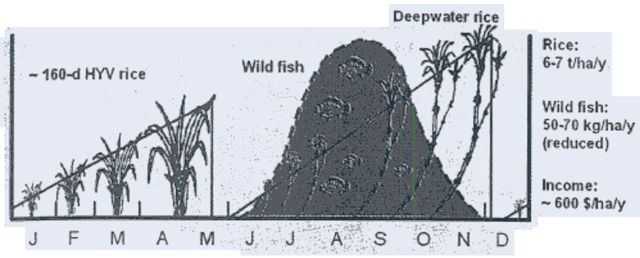

Figure 3. Evolution of farming system in floodprone areas: Moderately deep flooding land: Rice followed by seepwater rice+fish (1980s)

Figure 4. Evolution of farming system in floodprone areas: Deep flooding land: HYV Green Revoluton followed by fallow (1980s-1990s)

dry season, followed by transplanted deepwater rice varieties during the rainy seasons (Figure 3); while the dominant pattern in deep flooded areas is single- crop irrigated HYV rice (Figure 4). Late harvest of HYV dry season (winter) rice does not allow timely establishment of a deepwater rice crop in the deep-flooded areas during the rainy season. In shallow flooded areas in red river delta (in northern Vietnam), farmers generally grow high yielding irrigated rice during the dry season, and a tall-growing local or higher yielding variety during the rainy season. In Mekong delta of southern Vietnam, where rice fields are also deeply flooded in the rainy season, two irrigated crops of high yielding rice varieties are grown with a flood fallow period in between. Though the introduction of irrigation based 'green revolution' technology has increased total rice production in flood-prone areas (from about 2 to 7 Mg ha^{-1} y^{-1}), the wild fish harvest from flooded rice fields has declined substantially (from 200 kg ha^{-1} y^{-1} to <100 kg ha^{-1} y^{-1}).

Fish Integration and Community Approach

An opportunity for further increased production in the flood-prone ecosystem is the integration of fish culture with rice farming. The flood-prone areas are seasonally flooded during the monsoon and remain submerged for 4 to 6 months. In these flood-prone areas, land ownership is fixed according to tenure arrangements during the dry season. But at times of floods during the wet season, individual land holdings are not visible and waters become a community property granting all community members access to fish. Therefore, it is essential that the rice-fish culture in the flood-prone ecosystem be undertaken by the rural community under a group approach. The group should include the landless who have traditionally accessed the flooded areas for fishing, but would lose this essential resource if they were denied access because the areas are stocked with fish. Generally, three rice-fish culture systems can be established in flood-prone areas: (i) concurrent culture of deepwater rice (with submergence tolerance) with stocked fish during the flood season followed by dry season rice in shallow flooded areas; (ii) concurrent culture of deepwater rice (with elongation ability) with stocked fish during the flood season, followed by dry season non-rice crops, and (iii) alternating culture of dry season rice followed by stocked fish only during the flood season (that is, without rice) in the enclosed area (for example, as in a fish pen).

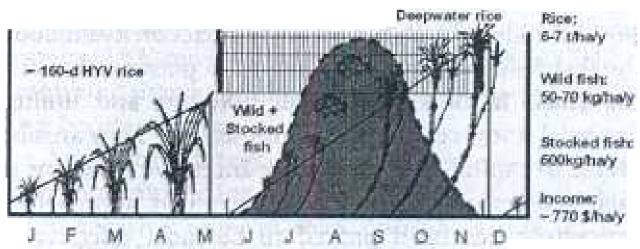

Figure 5. Evolution of farming system in floodprone areas: Moderately deep flooding land: Rice followed by deepwater rice+fish (2000s)

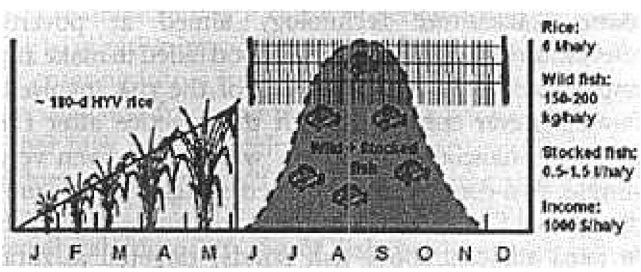

Figure 6. Evolution of farming system in floodprone areas Deep flooding land rice followed by fish only (2000s)

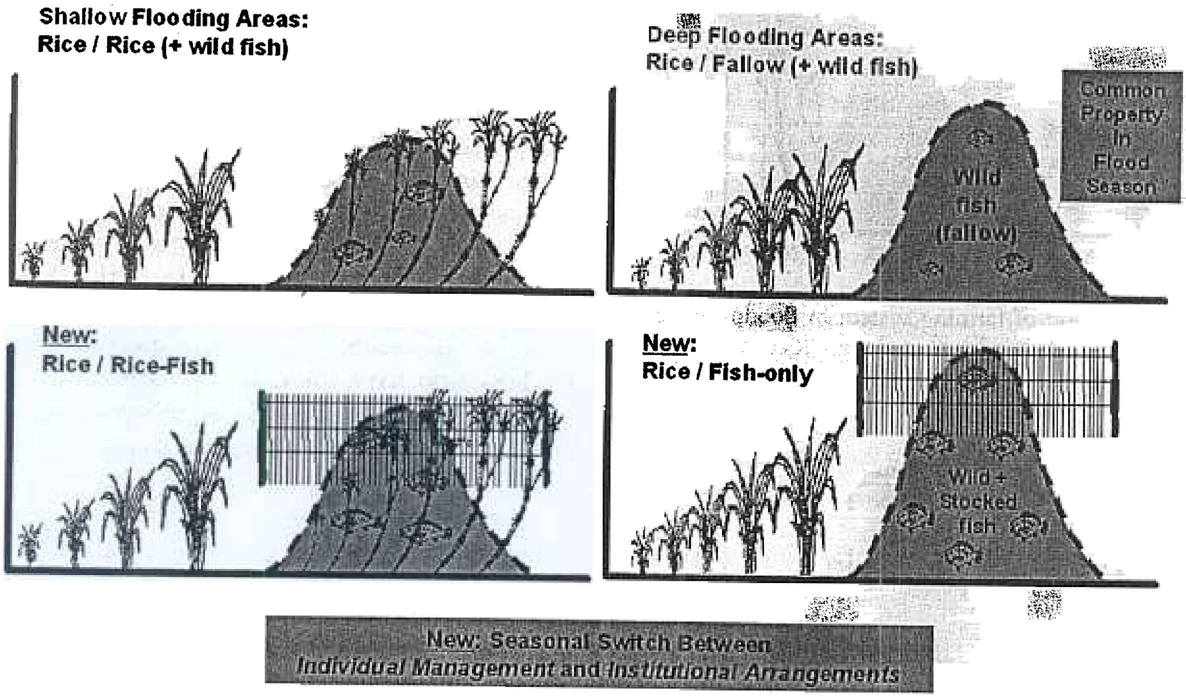

Figure 7. Seasonal floodplains: Two options for improvement of farminhg systems through community based fish culture

ROLE OF IAA IN RURAL LIVELIHOODS

In order to be effective in making impact on livelihoods, the technologies targeted at the rural poor need to suit the small farmers with small holdings and limited financial resources and hence risk-averse. They are also averse to capital- and knowledge-intensive solutions to their problems. Integrated management approach in agriculture has been proved to be most effective in making quick positive impact on rural livelihoods as it meets the conditions mentioned above to a large extent. Some other major considerations are: low risk to farmers, requiring low investment, providing quick returns, and to be simple to conceive and operate. There are many examples where propagation of stand-alone aquaculture technology aimed at poverty alleviation and sustainable livelihood failed to make any impact in the past. On account of the risk involved, farmers never continued with the practice after the external financial support was withdrawn. Even very simple, two-component packaged systems with a uni-directional flow of wastes (e.g. chicken-fish and pig-fish in pens adjacent/above fish ponds) targeted at rural poor failed to deliver. The main drawback of these systems was the requirement of separate enterprises at high levels of productivity and inputs in order to maintain a steady supply of required quantities of nutrients. The poor farmers did not have the financial resources or managerial capacity to maintain such systems.

Conversely, integrated systems, being easily adaptable, smoothly fit into the existing traditional crop-livestock farming framework. Being flexible, the farmer himself can determine the scale and intensity of operations at low or no risk. The main motivations that enable farmers in adopting IAA are to:

a. reduce risk from cropping,
b. accumulate capital
c. provide draught animal power, manure for fertilizer and fuel (in case of livestock),
d. satisfy cultural needs
e. enhance prestige/status
f. provide food, and
g. generate income.

Recent studies show that considerable nutritional benefits accrue to the producing households from the IAA either from direct consumption of fish or through purchase of food from the additional income generated (Prein 2002). Considering the high nutrition value of fish, particularly for vulnerable groups such as infants, pre-school children, and pregnant and lactating women, this can be considered as a very significant impact on the rural communities. Other direct benefits from rural integrated aquaculture are local availability of fresh fish and the provision of employment for household members. Indirect benefits include increased availability of fish to local and urban markets that may lead to a reduction in prices; increased employment benefits through development of an industry providing work on fish farms and related services; development of seed supply networks; and sharing of investment in community managed pool resources such as water bodies, cages; and in integrated pest management in rice-fish culture (Edwards 1998).

The benefits of aquaculture for poor women in rural Bangladesh have been shown to be substantial. In numerous cases, women-headed households have been able to obtain income and achieve tangible levels of relative prosperity. The importance of integrating aquaculture into future rural development programs has been underlined by NACA/FAO (2000).

There are many instances, where IAA has made significant impact on rural farming communities. A rice-fish-Azolla-banana-vegetable system in Malawii has been reported to make definite impact in terms of adoption and increased productivity. Once introduced in a rural community, the technologies have spread and evolved without further extension support, indicative of net benefits to the households adopting them. A field day was organized to explain the new opportunity to farmers and within six months the community has accepted it. About 46% of the farmers in the target area adopting the rice-fish farming practice had learnt about it from other farmers, a third of these farmers had adopted two or more technologies from their neighbors. After two years, it has been found that 80% of the farmers who were practicing integrated rice-fish farming in Zomba district had never witnessed first hand an extension demonstration (Chikafumbawa 1994, Brummett 2002). Integrated farms generate almost six times as much cash as typically generated by Malawian small farmers (Chimatiro and Scolz 1995), resulting in three times higher net income than the staple maize crop and homestead combined. On a per unit area basis, the vegetable- garden pond resource systems generates annually almost US$14 per 100 m^2 compared with US$1 and US$2 for the maize crop and homestead respectively, from an equivalent area. If this level of economic returns is sufficient to overcome recurrent cash flow problems of small holding farmers and to give them enough cash to reinvest in their farms, then integrated farming could contribute significantly to real economic growth in rural communities (Brummett 2002).

ECOSYSTEM CONSERVATION

Rice-fish systems foster ecological conservation through a number of means such as use of natural organic inputs, least alteration in the physical habitat, safeguarding agro-biodiversity (both rice and fish), allowing free movement of wild stock (in flooded systems), efficient recycling of farm wastes, utilizing all possible synergisms in various farm sub-systems, encouraging community and participatory approach in managing the resources which can facilitate mass awareness on conservation. A most striking environmental advantage of integrated system, especially when operated in small or medium intensity, emanates from the efficiency at which nutrients are managed. On small farms, these inputs are mainly in the form of wastes from crops and other plants, as farming in Asia is crop-dominated and the amounts of livestock wastes available are negligible (Prein 2002). This obviates the need for chemical fertilizers. Small farms are usually nutrient limited and are not over-fertilized and as a result, they achieve high nutrient-use efficiency and economy. Although, as low input systems they cannot produce high volume outputs, IAA can produce high value outputs such as freshwater prawn or small indigenous species, which have become scarce.

Small-scale integrated farming systems are more efficient at converting feeds into fish and these produce fewer negative impacts than purely commercial fish farms. They also do not use one human foodstuff to produce another (Brummett 2002). Manufactured fish feeds use a large quantity of land and aquatic animals and plants or their derivatives for protein, which can otherwise form food for humans or livestock. Large-scale collection of these organisms from the wild for feed manufacture is a cause of serious concern firstly due to negative impact on the biodiversity and secondly by entering into a 'protein trap' where cheap proteins are snatched from the mouth of the poor to produce other high value proteins for the consumption of the affluent. Brummett (2002) has illustrated that culturing tilapia in 1m^2 cage system involved 21,700 m^2 ecological footprint (6g of fish produced per m^2 of footprint) while the corresponding figures for supporting a 1m^2 waster-fed integrated fishpond for raising tilapia was 1.8 m^2 (264g of fish produced per m^2 of footprint). Given the implications of diverting materials such as fishmeal, fish oil and other proteins for feed manufacture; encouraging fish production with minimum dependence on manufactured feed has many long-term environmental and socio-economic benefits.

The floodplain farming system being evolved based on the Bangladesh and Vietnam experiment, described in the earlier sections, holds bright prospects for a reasonably win-win situation from an ecological and socio-economic point of view. Here, the natural fish habitat as well as fish stocks are retained at least for some part of the year and the fish are allowed to move from floodplain to river and *vice versa*. This is in sharp contrast to the general tendency among rice–fish farmers to cut off the floodplain from river to stock limited number of species for fattening.

Biodiversity

Under the rice-fish culture systems, the complex and diverse food webs of microbes, insects, predators and plants and livestock husbanded provide beneficial effects to one or both compartments. This is in sharp contrast to the intensification of rice and fish through monoculture, which leads to short-term gains but to long-term non-beneficial effects and biodiversity loss. From a biodiversity perspective, rice-fish farming systems contain: (a) low to moderate rice genetic diversity in HYV due to intense varietal selection primarily for yields and secondarily for system maintenance and economic viability, and (b) moderate to high fish species diversity, with low selection of varieties within species. High biodiversity levels occur in traditional, low intensity, rain-fed systems.

WIN-WIN SOLUTIONS

Like any other developmental efforts for harnessing natural resources for food production and income generation, IAA tools need to be used within certain limits of environmental, social and economic sustainability. All winning situations like increased food production, higher income generation, increased employment should be weighed against their possible negative impacts such as environmental degradation, denial of access, erosion of livelihoods and inequitable distribution of benefits among stakeholders. There are many constraints (temporal, spatial and technological) that could come in the way of implementing the system and many a times, intra- and inter-sectoral conflicts in resource use could arise, undermining the very purpose of development. In order to overcome these constraints and resolve the conflicts, it is important to have a governance system that ensures equitable distribution among stakeholders and their effective participation in decision-making process. In an ideal system, yield optimization is achieved and equity ensured with little disruption in environmental quality. Although such ideal situations seldom exist, it is desirable to search for system where the genuine environmental and social concerns are addressed adequately. Such a win-win solution should take into account some key components of the system and attempt to set parameters to measure them. They are: Scale of operation, Selection of species, Right mixing of traditional and new approaches, and Community approach.

Scale of Operation

Sustainability of IAA is closely linked with the intensity at which it is operated, the two often negatively correlated to each other. Aside from making it environmentally unsustainable, upward scaling makes the system beyond the reach of the resource-poor, risk-averse small holders, breeding a new set of social and economic concerns arising out of issues related to access, livelihood, income generation, distribution of benefits and traditional right to resources. In addition, this way, all the household benefits like nutrition, additional income and women's development as described in earlier chapters become unattainable. Inflated scale demands higher quantity of nutrients and feed, the production and management of which will put additional pressure on farm space, inputs and management capability. This will necessitate more capital to develop complex modification of the farm design and operation, leading to a situation where the benefits derived from the technological innovation will flow to an already resource-rich investor (or a small group of them), rather than the local communities who have traditional right to access to the resource.

Thus, the intensity of operation holds the key for making the system environmentally sustainable and socially viable. However, it is important to determine the indicators for measuring the scales of operation. Some possible criteria are: (i) level of farm modifications, (ii) quantity of inputs used (iii) level of monetary input for capital and operation and (iv) yield level, which can be considered singly or in combination (Table 3).

Table 3. Checklist for indicators of win-win solutions

(1) Scale	(2) Species selection (Fish)	(3) Variety selection (Rice)	(4) Right species/variety mix (Various combinations of 2 & 3)	(5) Governance
Level of Modification of farm	Natural stock	Traditional		Common property (all)
Quantity of Inputs used	Herbivores	Deep water		Common property (fish)
Capital and operating cost	Rice field dwelling (all)	Deep water (floating)		Individual ownership
Yield level	Exotic	HYV (pest-resistant)		
–	--	HYV(not pest-resistant)		

Selection of Species

A major consideration affecting the success of IAA is the selection of fish species and rice varieties. Some high yielding varieties of rice that demand heavy dose of pesticides and fertilizers are not conducive for a successful operation. Ideal fish species for IAA are those naturally inhabiting the rice field ecosystems. Other important criteria for selecting fish species are their feeding habits, growth and ability to control rice pests. Fish feeding on plants or plankton convert energy more efficiently than those living on a longer food chain. Fish stocked in the rice-fish system has either has open access to the river or they are vulnerable to be strayed into natural waters. Therefore stocking exotic species and repeatedly bred farm fish seed are not ideally suited for the system. Alternate use of wild and stocked fish as described in the case studies of Bangladesh and Vietnam augurs well from an ecosystem point of view. Carnivorous fish, if selected, should use natural food in the system as feeding them with fish or fishmeal is not a sustainable practice. A good example of winning solution is the practice of collecting animals from the neighboring fields and wetlands and feeding the fish stock. An instance of collecting golden apple snail (which is pest to paddy) from fields, crushing them and feeding them to stocked fish has been described here.

Traditional and New Approaches

Rice fish integration operates under a very wide range of technological options. While the traditional practice involves catching the wild fish from the rice fields, the improved versions essentially mean creating an artificial environment in the rice field to stock and grow fish before they are caught. However, there are different scales between these extremes. Obviously, sole dependence on wild fish may not be economically viable due to low catch. At the same time it is understood that rice field should not be converted into an intensive aquaculture pond. In order to take the inherent advantages of the combined system, the fish should utilize the ecosystem goods of rice fields. This calls for creating a right mix of capture, culture and enhancement component while managing the fishery. The floodplain rice-aquaculture system demonstrated in Bangladesh is an ideal win-win solution to take full advantage of the traditional (capture) and new (culture) systems in different seasons of the year.

Community Approach

A key requirement for win-win situation is development and operation of a good governance system based on community approach in managing the IAA operations. This helps to ensure equity, minimize conflicts among stakeholders and ensure easy resolution of conflicts, should they arise. This works very well in floodplain rice-fish culture, where in spite of individual ownership of rice plots, fish culture is done on a community basis. This approach has many advantages like providing an extended habitat for fish to feed and grow and allowing plenty of natural fish food organisms to fish stock, obviating the need for artificial feed and facilitating higher cash flow for reinvestment. Under a community dispensation, the income generated from the fish catch is divided equitably based on the size of land holdings, contribution to the operating expenditure and a number of other locally agreed criteria. The system has been found very successful in Bangladesh and Vietnam.

One example of the win-win solution is the community-based floodplain rice-aquaculture system being developed in Bangladesh and Vietnam. Similar models need to be developed for other situations elsewhere.

REFERENCES

Alam, A.K.M. and van der Hoek, H. 2001. Increasing wild fish harvests by enhancing rice filed habitats. Pages 215-221, In: IIRR, IDRC, FAO and ICLARM. Utilizing Different Aquatic Resources for Livelihoods in Asia. International Institute for Rural Reconstruction, Cavite, Philippines.

Brummett, R.E. 2002. Realizing the potential of integrated aquaculture: Evidence from Malawi. pages 115-124, In: Uphoff, Norman (Editor) Agroecological Innovations, Increasing Food Production with Participatory Development, Earthscan Publications Ltd., London, Sterling, VA,

Chen, H., Hu, B. And Charles, T. 1995. Chinese integrated farming: a comparative bioeconomic analysis. Aquaculture Research 26: 81-94.

Chikafumbwa, F.J.K. 1994. Farmer participation in technology development and transfer in Malawi. Pages 30-31, In: Brummett, R.E. (Editor) Aquaculture Policy Options for Integrated Resource Management in SubSaharan Africa. ICLARM Conference Proceedings 46. International Center for Living Aquatic Resources Management, Manila, Philippines, and GTZ, Eschborn, Germany.

Chimatiro, S.K. and Scholz, U.F. 1995. Integrated aquaculture-agriculture farming systems: a sustainable response towards food security for small-scale poor farmers in Malawi. Presented to the Bunda College Aquaculture Symposium, Lilongwe, Malawi, 11 February. 25 pages.

Demaine, H. and Halwart, M. 2001. An overview of rice-based small-scale aquaculture. Pages 232-240, In: IIRR, IDRC, FAO and ICLARM. Utilizing Different Aquatic Resources for Livelihoods in Asia. International Institute for Rural Reconstruction, Cavite, Philippines.

Edwards, P., 1998. A systems approach for the promotion of integrated aquaculture. Aquaculture Economics and Management 2(1): 1-12.

IIRR-ICLARM, 1992. Farmer- Proven Integrated Agriculture – Aquaculture: A Technology Information Kit. ICLARM, Manila, Philippines, and IIRR, Silang, Cavite, Philippines. 29 pages.

Johnson, D., Clough, B., Xuan, T.T. and Phillips, M. 1999. Mixed shrimp-mangrove forestry farming systems in Ca Mau Province, Vietnam. Aquaculture Asia 4(2): 6-12.

Kapetsky, J.M. 1995. A first look at the potential contribution of warm water fish farming to food security in Africa. Pages 547-572, In: Symoens, J.J. and Micha, J.-C. (Editors), The Management of Integrated Freshwater Agro-Piscicultural Ecosystems in Tropical Areas. Technical Centre for Agricultural and Rural Cooperation (CTA), Wageningen, and Royal Academy of Overseas Sciences, Brussels,

Li, Kangmin, 2001. Rice-based aquaculture in China. pages 241-246, In: IIRR, IDRC, FAO and ICLARM. Utilizing Different Aquatic Resources for Livelihoods in Asia. International Institute for Rural Reconstruction, Cavite, Philippines.

Lightfoot, C., Bimbao, M.P., Dalsgaard, J.P.T. and Pullin, R.S.V. 1993. Aquaculture and sustainability through integrated resources management. Outlook on Agriculture 22(3): 143-150.

Mathias, J.A., Charles, A.T. and Hu, B.T. 1997. Integrated Fish Farming. Proceedings of a Workshop on Integrated Fish Farming, 11–15 October, Wuxi, Jiangsu Province, P.R. China, CRC Press, Boca, Raton, Florida, USA. 432 pages.

NACA/FAO, 2000. Aquaculture development beyond 2000: the Bangkok Declaration and Strategy. Pages 463-471, Conference on Aquaculture in the Third Millenium, 20-25 Feb-ruary,2000, Bangkok, Thailand. Network of Aquaculture Centres in Asia, Bangkok, Thailand, and FAO, Rome, Italy.

Prein, M. 2002. Integration of aquaculture into crop-animal systems in Asia. Agricultural Systems 71: 127-146.

Pullin, R.S.V. and Mark, P. 1995. Fish ponds facilitate natural resources management on small-scale farms in tropical developing countries. Pages 169-186, In: Symoens, J.J. and Micha, J.C. (Editors) Management of Integrated Freshwater Agro-Piscicultural Ecosystems in Tropical Areas. Technical Centre for Agricultural and Rural Co-operation (CTA), Wageningen, and Royal Academy of Overseas Sciences, Brussels.