ATTRIBUTES OF SMALLHOLDER FARMING SYSTEMS

Small-scale farming in rural areas worldwide is almost always done in a way which combines several production components. Different from large-scale monocultures, such as palm oil plantations or the production of sugar-cane or wheat on hundreds of hectares, a typical smallholding produces different crops and vegetables, and rears livestock. Such farming systems are beneficial to the farmer for two main reasons:

- Combining several production components decreases the risk element which agriculture entails. If one component fails, the other can provide the critical mass for survival;
- The different components interact in a symbiotic and synergetic manner, enhancing overall production, optimising resource use and thus providing for the subsistence needs of the household. Trees provide shade for crops and livestock while producing fruit; livestock manure is used as a fertilizer and crop by-products are fed to animals.
Smallholder farming systems have evolved over centuries. Their technological and socio-economic features are part of the indigenous knowledge of the social group for whose basic needs they provide.

WHY INTEGRATE AQUACULTURE INTO SMALLHOLDER FARMING SYSTEMS?

FOR CENTURIES, FARMERS IN ASIA AND CENTRAL EUROPE have integrated pond culture into diverse farming systems using techniques which rely almost exclusively on the recycling of by-products from animal and crop production. Commonly used feeds include oilcakes and cereal brans while manure is used as pond fertilizer.

MATERIAL FLOWS AND LABOUR RELATIONSHIPS IN A SMALLHOLDER FARMING SYSTEM IN BANGLADESH

In many rural areas of Europe, such as in parts of Bavaria, Germany, aquaculture in earthen ponds is an integral part of agricultural farming systems. Many of these ponds were constructed during medieval times, on land that had no or little value for conventional agricultural cropping. Their primary objective was, and commonly still is, to store water (for watering livestock and fighting fires), and to improve water retention and thus maintain the groundwater table at a level suitable for agriculture. The ponds also served an additional function, which was the production of common carp. Nowadays, these integrated farming systems contribute significantly to carp production in Bavaria.

Since medieval times, the management patterns of carp production as part of an integrated agricultural farming system has remained virtually unchanged. Livestock manure is used to fertilize the ponds. Carp are stocked at an extensive level and fed with low cost feed such as farm by-products. Although not common now, the rotational draining and cropping of pond soil was also widely practised to make use of, and recycle, the nutrients trapped in the bottom sediments. Specialized commercial fish traders often undertake the harvesting of carp, therefore keeping operational costs to the farmer to a minimum. An economic assessment of such practices has indicated that revenues from fish sales might only just cover expenditures. However, fish production spreads farm inputs and diversifies outputs, and thus reduces management risk. Moreover, farm managers perceive extensive fish farming as a means to assure a certain degree of subsistence, and to maintain an asset in times of crisis.

Pond culture has a number of advantages, in terms of inherent production efficiency, over crop production and livestock rearing. The three dimensional aspect of a pond habitat offers a variety of ecological niches which can support numerous and diverse organisms. In China, a well-managed pond is stocked with more than eight different fish species all of which can grow well because they occupy different parts of the pond water and exploit these different nutritional niches. In addition, aquatic animals are cold-blooded and therefore expend more energy on growth rather than on the maintenance of body temperature. Also, they make use of both natural and added feeds.

There are several potential advantages that can be derived from integrating aquaculture with other smallholder farming system components:
Decreased risk
The diversification of farming systems to include aquaculture diminishes the risks associated with small-scale farming. This is because pond water not only yields fish, an edible and tradable commodity, but can also contribute to crop irrigation and livestock watering in the dry season, thereby increasing the viability of year-round production.

Improved food and economic security
The extra production from aquaculture can imply an increased availability of protein for household consumption. Alternatively, aquaculture products can be treated as a commodity which can be traded for cash or essential household items. Both strategies increase household economic security.

INTEGRATION OF AQUACULTURE INTO SMALLHOLDER FARMING SYSTEM IMPROVES FOOD AND ECONOMIC SECURITY
A study in the Philippines demonstrated that although a shift from rice monoculture to rice-fish farming requires a 17% increase in labour investment and an initial 22% increase in investment capital, the additional fish production increases overall farm income by 67%. A project with 256 farmers in Bangladesh revealed that net benefits of the integration of fish farming were more than 20% to rice cultivation alone as farmers stocking fish used less fertilizer and pesticides. Overall net benefits in integrated systems were 64% higher in the dry season and 98% higher in the wet season.

Enhanced production
Certain edible plants, such as Chinese water spinach and water chestnuts, can be cultivated in fishponds. With adequate flotation and support, so can some terrestrial vegetables and herbs. Other plants which grow in ponds without additional inputs, such as azolla, duckweed or water hyacinth, can be used as green manure or compost to enhance soil fertility, or as fodder for fish and livestock. Also, seasonal or rain-fed ponds may be used for crop production.
when they fall dry during the dry season, using no additional water or nutrient sources. Rotations between aquaculture and agriculture have been shown to improve soils over time.

Multiple use of ponds
The water in aquaculture ponds need not only serve to culture fish. In parts of South Asia, fishponds are used for bathing and irrigating homestead fruit and vegetables, others for disposing of domestic wastewater. As a source of irrigation water, pond water is usually richer in nutrients than well water and also contains nitrogen-fixing blue-green algae which can improve soil fertility. After the fish harvest, nutrient-rich pond mud can be used as fertilizer or the pond can be used to grow forage and other crops.

In areas where seasonal water shortages occur, a pond can be vital for ensuring year-round crop production, livestock watering, domestic water supplies and fire protection.

Environmental benefits
Where farm wastes are produced in significant quantities, their application into aquaculture ponds not only leads to a more efficient system, but prevents them from being disposed into the environment. Some forms of integrated aquaculture, such as rice-fish farming, can decrease if not eliminate the need

**THE MULTIPLE USE OF PONDS FOR AQUACULTURE AND IRRIGATION INCREASES FARMERS’ INCOMES**

The availability of pond water for irrigation in integrated farming systems in north-east Thailand has considerably increased farm incomes. The farmers have been able to produce and sell agricultural products during the relatively non-productive dry season at higher prices. Although the quality of pond water gradually deteriorates throughout the dry season, the farmers have adapted to this by culturing a hardy species of air-breathing catfish, which thrives well under the poor conditions.

In Africa, the realisation of the benefits of integration has led to its increased promotion, e.g. in various projects supported by the FAO Special Programme for Food Security. Recently, five countries (Burkina Faso, Côte d’Ivoire, Ghana, Mali and Zambia) have formed a network to promote the benefits of integrating aquaculture and irrigation.

RICE FARMERS of Bangladesh have traditionally taken advantage of the seasonal migration of fish into their rice fields. During the monsoon, when flood waters over-top paddy fields, wild fish enter into the fields where they profit from the availability of natural food and the protection offered by rice stems. As the floods recede, the fish are trapped and are harvested along with the rice.

CARE, through funds from the UK Department for International Development, has encouraged farmers to build on and improve this traditional approach. Some 70,000 farmers have benefited from new approaches in rice-fish farming, which involve the additional stocking of fish into paddy fields during the rain-fed and irrigated rice seasons, and improved field management practices.

Integrated rice-fish farming not only benefits the farmers in terms of more income, more food and less labour, but is also environmentally and ecologically sound. Energy and nutrients are recycled more efficiently through the food chain, creating a stable and highly productive system. Fish feeding and swimming activities generally improve the fertility of the soil.

Weed growth is frequently a problem in rice fields which farmers usually address through labour-intensive manual weeding or the application of expensive herbicides. When stocked in rice fields, grass carp, which feeds exclusively on macrophytes, can effectively control weed growth, thereby reducing labour and costs.

In rice monoculture, farmers often control rice pest infestation with costly pesticides. The resulting residues absorbed by rice grains can concentrate in the human body at rates of up to 15 times higher than the WHO recommends. Pesticides not only eradicate nuisance insects but also beneficial ones, thereby reducing the species diversity and ability of the rice to withstand further pest attacks. A farmer who has stocked a rice field with fish is unlikely to use pesticides as the benefit derived from the fish, in economic terms, outweighs the damage to the rice by pests.

SOURCE: DFID, personal communication

for harmful pesticides. Some fish species not only eat rice pests but also disease carrying organisms of human health importance, such as mosquito larvae or snails. When appropriate fish species are stocked in rice fields, the feeding of the fish on weeds and algae, and their subsequent excretion, not only reduces the need for herbicides but also increases phosphorus and nitrogen levels in the water. This therefore reduces the requirement for chemical fertilizers.
The reasons for regional differences in the growth of aquaculture have been the subject of several comprehensive evaluations and consultations listed in the bibliography section of this brochure. A selection of lessons learnt and successful examples is provided here.

In parts of Africa and Latin America, one major impediment to the growth of aquaculture has been the overzealous and unplanned promotion of the technology. These approaches have often ignored, or have not taken sufficient account of, the socio-economic, cultural and environmental conditions in the traditional farming systems but were largely focused on technical research and technology transfer. However, fish farming, when promoted as a single component technology, does not fit within rural farming systems whose prime objective is survival, because it diverts and reduces inputs which are needed to ensure household economic security. The failure to recognize the limitations of introducing aquaculture into African rural development might have been prevented if aquaculture had been promoted as an integrated component of rural farming systems.

Even aquaculture introduced on a small scale requires capital investment. Unfortunately, in the rural environment of developing countries there is little such capital available for new investments. Cash is conserved for expenditures such as school fees and medical emergencies. Cash outlays for farming purposes are made when virtually no risk is involved, e.g. for additional labour and marketing costs incurred during harvests.
A CENTRAL CONSTRAINT to the sustainable establishment of aquaculture in sub-Saharan Africa is an issue of development policy. Aquaculture development in sub-Saharan Africa is largely focused on small-scale freshwater pond culture, which most development agencies have introduced with the objective of equitably improving food security and livelihood resilience amongst the resource poorest. Unfortunately, this group is rarely able to maximise the opportunities presented by aquaculture, because they do not have the assets required to establish and sustain a new and demanding technology. In focusing on the resource poorest, development agencies usually ignore those who have access to these resources and thereby bypass an opportunity to facilitate the sustainable development of aquaculture.

The rationale of the policies of external assistance agencies to promote aquaculture for the potential social and economic benefits of rural small-scale farming was based on a number of assumptions:

- fish farming is a technology easily within the grasp of small-scale farmers;
- the majority of the produce would be for home consumption, and therefore an incentive for the farmer to take ownership of the technology;
- inputs, in terms of feed, fertilizers and labour, would be available in abundance and at low cost.

Most of these assumptions have been proved wrong. The technological know-how required for economically successful pond culture is demanding. Also, to promote fish farming for home consumption is often the wrong approach in motivating farmers to take up aquaculture. Fish, unless caught occasionally and in non-marketable quantities, is always considered a cash crop in the African context. While food security is an integral part of the coping strategy of rural households, fish production is not part of this strategy and would always serve a priori to earn cash. Fertilizing and feeding is also relatively unfamiliar to the rural small-scale producer in Africa. Fertilizing of plots is, if at all, done irregularly in small-scale traditional agriculture. In addition, feed and fertilizers available for fish farming usually have tangible opportunity costs. Even when operating on a low-input basis, it is difficult to convince small-scale farmers to invest inputs in a production system not known to them. Fish farming requires considerable labour input, even if practised on a small scale. The potential of increased household consumption is not often a sufficient incentive to convince farmers to tend to their ponds regularly.

Also labour can be a scarce commodity in rural areas, particularly in Africa. In spite of this, economic analysts have often assumed that labour in small-scale farming has little or no opportunity costs. They calculated that relatively labour-intensive technologies, such as fish farming (when compared to other components of a smallholder farming system) would be feasible in sub-Saharan Africa or Latin America because of a labour abundance. In reality, this labour abundance frequently does not exist.

Often, the needed quality and quantity of fish seed are not readily available to the farmers at the right time, or the costs of obtaining fingerlings is prohibitive because fish seed is produced in few central hatcheries too far for farmers to reach. A network of private, decentralised hatcheries has been the key to success to integrating aquaculture into farming systems in several countries.

PRIVATE FISH SEED PRODUCERS DRIVE THE ADOPTION OF FISH CULTURE IN RICE-BASED FARMING SYSTEMS IN MADAGASCAR

For aquaculture to ultimately contribute to sustainable rural livelihoods it has to function largely as a private sector activity. The Malagasy Government together with the UNDP-FAO project on “Promotion de l’aquaculture et privatisation de la production d’alevins”, elaborated a new approach to develop rice-fish farming in the highlands of Madagascar. A network of private fingerling producers was set up gradually, and as a private producer became operational, fingerling distribution by the Government in that area was discontinued. In a next step, extension services for rice-fish farmers in the area were included in the marketing strategy for fish seed producers, ranging from demonstration of own rice-fish operations to the organization of meetings. To achieve this, fingerling producers were trained in marketing methods, teaching skills, and extension methods. Activities were supported by a small but highly qualified group of government extension agents.

There are other issues which have constrained small-scale aquaculture development. The introduction of aquaculture to regions where it is not a traditional pursuit has often relied on institutional technical support provided by aquaculture extension services. Many countries now have these services, but their effectiveness has not always reached expectations. Innovation has often been attempted in abstraction from the broad set of environmental, social and cultural conditions which determines a given farming system, and via extension agents trained only in a single component technology. However, innova-

**ALTERNATIVE EXTENSION APPROACHES - EXPERIENTIAL LEARNING IN FARMER FIELD SCHOOLS IN VIET NAM OPENS OPPORTUNITIES FOR THE INTEGRATION OF AQUACULTURE**

- **THE APPROACH TO REACH** and enhance human expertise for Integrated Pest Management (IPM) is via Farmer Field Schools (FFS) with about 25 farmers each. Farmers e.g. in Indonesia, Viet Nam, Cambodia, Ghana, Burkina Faso, Mali, Côte d’Ivoire, spend 5 to 6 hours together weekly out of which 2 hours are spent in the field observing the ecosystem.

- **IN VIET NAM**, financial benefits per ha surveyed in a sample of FFSs in more than 1 300 villages averaged 20-25% higher in IPM fields than in regular fields. Part of this came from a yield increase (4%). This increase in turn resulted in large part from farmers taking money out of pesticides and putting it into fertilizers as well as from a change in the timing of the fertilizer application. Timing changed because of the farmers’ better understanding of the crop ecosystem. In FFS, farmers are consciously looking at the ecosystem, making and acting on decisions in order to get better production. Thus FFS provide the technical base for farmer empowerment. Frequently, these farmers groups stay together even though investment from outside has long ended.

- **NEARLY ALL THE EQUIPMENT needed in FFS are plastic bags, pencil and paper.** Farmers put samples of arthropods in plastic bags and after the field work they go to discuss in small groups about what they have observed, prepare poster diagrams, and present findings to their fellow farmers.

- **FARMERS OBSERVE POPULATIONS in the field but also test their trophic linkages by setting up “insect zoos”**. These answer their questions on ‘what eats what’ and ‘how many are eaten’ etc. Such experiments are interventions that advance farmers’ knowledge and lead to further experimentation.

- **ELIMINATION OF NEARLY all pesticides results in a higher biodiversity which frequently is used by farmers in a sustainable manner. Snails, frogs, aquatic...**
ative extension approaches with emphasis on the participation of target groups show that the integration of aquaculture into smallholder farming systems holds great promise for success.

Examples of successful integration of small-scale aquaculture into smallholder farming systems typically have in common that both the resources necessary for economical viability and markets are available and that the aquaculture component is closely linked with the other components of the farming system.

Incentives and Approaches for the Conservation and Sustainable Use of Biological Diversity in Agricultural Ecosystems and Production Systems. FAO, Rome, Italy.

insects and others constitute an important part of the diet of many rice-farming households.

• WHERE WILD AQUATIC RESOURCES are declining from habitat change then culturing fish in rice fields or adjacent water bodies becomes increasingly important; particularly because fish comprise more than 50% of animal protein eaten in Asia.

• FARMERS’ ADVANCED knowledge about rice field biodiversity together with vastly reduced pesticide levels thus opens new opportunities for food security and income generation: many rice farmers decide to make double use of their fields and the rice field aquatic ecosystem by raising fish.

• THEY EXPERIMENT with different management options, growing a “crop” of fish together with the rice in the same field, using the rice field to grow a crop of fish between two rice crops, or growing fish after rice instead of a second rice crop.

Farmers also experiment with physical modifications of the fields to accommodate the fish such as digging trenches in different shapes and sizes or small ponds at different locations. They are innovative in adapting their production systems to local market conditions - growing bigger fish for sale or their own consumption or smaller fish if they can sell them to grow-out operations nearby.

• BETTER UTILIZATION of resources, increased income, and a healthy crop of rice and fish reinforce farmers’ acceptance of integrated pest management and rejection of pesticides.
VIET NAM

THE VAC SYSTEM

The Vietnamese saying “Nhat canh tri, canh vien” says that the first profitable activity is aquaculture and the second is agriculture, horticulture, or gardening. It is estimated that about 30% of the households in rural areas in Viet Nam have multi-purpose ponds producing fish. Integrated farming is a traditional approach to ensure food security in the poor, rural regions of Viet Nam. The integration of the homestead, garden, livestock, and the fishpond is called the VAC system.

The VAC system can be found in irrigated lowlands, rainfed uplands, and peri-urban areas of Viet Nam. In a typical upland system, the pond, livestock pen, garden and homestead are located close to each other to facilitate recycling of wastes. A mix of annual and perennial crops is cultivated including vegetables and fruits, sugar cane, tea, and cassava. Cattle, pigs, and poultry wastes are used to fertilise perennial crops once or twice a year, and vegetables as needed. Also pond mud is used as fertilizer once every 3-4 years.

The pond area usually ranges from 100 to 1 500 m² in which a polyculture of several species of Chinese and Indian carps are stocked at densities up to 2 fingerlings per m². Kitchen wastes, livestock manure, and green manure are generally used as pond fertilizers. After a culture period of three months the pond is continuously harvested and re-stocked. Annual yields of 2 000 to 3 000 kg per hectare are commonly achieved while semi-intensive systems especially with tilapia may reach 4 500 to 5 500 kg per hectare.

IN GUATEMALA, AN INTEGRATED fish pond project was initiated in 1982 as a collaborative effort of the National Directorate for Livestock Services, CARE, USAID, and the Peace Corps. Auburn University provided technical assistance in fish culture to the Government of Guatemala and CARE. The project was designed to improve nutrition and income for poor farm families in eastern, coastal and northern Guatemala. To do so, the project promoted small-scale fish culture on small, individually owned farms. On many farms, 100 to 200 m² hand dug ponds were integrated with livestock. The manure was used to fertilize the pond waters to increase fish yields and the nutrient-rich pond mud was used to fertilize gardens adjacent to the ponds. The target population - poor farmers - had an average land holding of 0.9 hectare per household and an average total annual income of US $700. By 1989, 1,200 ponds had been built or renovated. About 15% of these ponds were integrated with animals and 21% with vegetable gardens.

In 1998, an evaluation team re-visited a representative sample of the 651 farm families known to have had functioning ponds when external financing was withdrawn. The team found that 13% of the ponds were well managed, 48% under-utilized, and 39% were abandoned. Eight percent of the farmers presently raising fish had animals integrated with their fish ponds while about 40% had experience with this form of integration at some time during the history of the project. Interestingly, it was more the integration of cattle and milk cows with fish ponds than the integration with poultry that proved to be sustained. Owners who do use cattle and milk cows in association with fish ponds are usually financially secure and feed their animals on pasture grass. Without a consistent source of manures to fertilize the fish ponds, producers resort to kitchen and table scraps, and on-farm by-products to feed the fish. Unfortunately, this is not sufficient to obtain high fish yields. Consequently, the net annual income from fish sales is modest although considering the poverty of the average participating household in the project the net cash value of the fish crop was equivalent to approximately 2 months of wages as a rural labourer.

More importantly, however, almost half of the pond operators revealed that a strong motive for retaining an active fish pond was the need for water during the dry season for irrigation and livestock watering. Most farmers had their irrigated gardens on land which received water by government controlled irrigation canals. Water was rationed during the dry season and farmers had permission to receive water once every two to three weeks. Thus, fish ponds were filled to capacity when water was available and water was dispensed as needed over the period when irrigation canal water was unavailable. Without the fish pond, vegetable production would be impossible or restricted during the dry season.
ZAMBIA - FARM DIVERSIFICATION THROUGH AQUACULTURE INCREASES FOOD SECURITY, INCOME, AND WATER USE EFFICIENCY

In Zambia, the FAO Special Programme for Food Security, with the help of ALCOM, is supporting a pilot programme on diversified farm crops through the integration of irrigation and aquaculture.

As part of this programme, farmers in Mkushi district have constructed over 50 fishponds, fed with water channelled from a spring or a river, on sloping land with gardens on both the higher and the lower level. Maize is the staple; other crops include rape, cabbage, onion, beans, pulses, groundnuts, eggplants, and tomatoes. Gardens are irrigated with pond water by hand or by gravity flow, and treadle pumps are used for irrigating up-slope gardens. Leftovers of food and of vegetable production as well as various wild plant leaves are very important feed inputs, and go into the ponds together with brewery waste, wheat bran, and chicken and rabbit manure, as available. Annual harvests of up to 2,500 kg per hectare are common.

Fish farming is viewed as an important activity particularly for farmers with livestock since disease problems with cattle have increased and armed theft of livestock is not uncommon in the area. Constraints vary from site to site but generally include management difficulties as well as the availability of sufficient numbers of good quality fingerlings. These constraints are however being lifted in quite a few areas with farmers increasingly engaging in the activity generating self-sufficiency in fingerling supplies and gaining more and more knowledge in practical harvesting, fertilizing and feeding techniques.

INTEGRATED FARMING SYSTEMS have been the subject of extensive research, not only in terms of their bio-technical rationale, but also regarding their social, economic, institutional and environmental implications. If aquaculture is considered as an additional component of a farming system, a re-assessment of the given conditions of the system is necessary. This is particularly pertinent in situations where aquaculture is not a traditional pursuit.

Unfortunately, there is no quick and easy blueprint for the successful and sustainable integration of aquaculture with the diverse range of smallholder farming systems. Social, economic, cultural, institutional and environmental factors vary from place to place, and will always need to be carefully examined and understood before embarking on the introduction of aquaculture into existing farming systems. In China, where people have been successfully integrating aquaculture with other farming systems for longer than most nations, the systems have evolved to harmonise with specific social, economic and cultural conditions. If these specific systems were to be transferred to other regions, there is no guarantee that it would be met with the same degree of success, because resource availability, know-how and traditional farming practices, as well as other aspects, are different.

Some important questions one has to ask when considering the integration of aquaculture into smallholder farming systems are summarised below:

**Sufficient Incentives**

Can the produce be marketed at relatively low cost and be afforded even by poorer consumers or, if the product is home-consumed, does it substitute a good or item which would have to be purchased by the household?

**Sufficient Resources**

Are the resources available to the farming systems (labour, water, land, initial capital etc.) sufficient for an additional aquaculture component? Are there seasonal fluctuations in the availability? Or can aquaculture replace an
existing component of the farming system providing more return with equal or less opportunity costs?

**Sufficient Know-how**
Is the know-how available within the household sufficient to successfully manage an aquaculture component, or is it available from outside on a sustainable basis/can it be transferred from outside?

**Reliable Supply of Production Inputs**
Are essential inputs, such as fish juveniles or breeders, feed, fertilizers available? Are these production inputs available at opportunity costs that make production economically viable?

**Reliable and Effective Development Support**
Is development support for the innovation of aquaculture available and accessible to the farmer? Is it reliable and efficient?

**Sufficiently Developed and Stable Market**
Is there sufficient and stable demand for the produce? Do price structures provide for economic feasibility considering instrumental and operational costs? Can peak harvests be absorbed?

**Social and Cultural Factors**
Is the inclusion of aquaculture in the targeted farming system socially and culturally acceptable? Does aquaculture conflict with given value and behaviour patterns? Can it create new problems, for example regarding the existing resource use system? Does it imply changes to existing production systems, for example from individual farming-based systems to collective production? Or could it have negative consequences for the existing gender-specific system of division of labour, for example, by putting additional burden on women?
In every given case of an existing farming system targeted for the introduction of an aquaculture component, these and other case specific questions need to be asked. If the assessment comes up with positive answers, the innovation of appropriate aquaculture technology is likely to enhance efficiency of the system.

To answer these questions, a series of methods and tools have been developed during the last two decades, such as rapid rural appraisal, participatory rural appraisal etc. Applying these and other similar methods and their respective tools, and considering aquaculture as one of several components of a given farming system may be a way of successfully introducing the technology, also in places where it is not part of the indigenous knowledge of the farmers.