Aquaculture Technology Research For Smallholder Farmers In Rural Malawi

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Abstract

In order to develop aquaculture systems and technologies relevant to the maize-based farming system in rural Africa, the International Center for Living Aquatic Resources Management (ICLARM) is conducting farmer-participatory research in Malawi. This involves farmer-researcher interaction throughout the aquaculture program, thus enabling researchers to: (1) assess farmers' agroecological resources and the extent of their traditional agricultural knowledge to provide information on the constraints to adoption of aquaculture; (2) develop on-station research to test technologies relevant to rural farmers and their farming systems; and (3) monitor and evaluate, in collaboration with farmers, the performance and impact of new technologies and integrated agriculture-aquaculture models on farming systems.

The research process involves a continuing transfer of information and ideas between farmers and researchers so that research agendas can be adjusted to meet changing needs as indigenous aquaculture systems evolve.

Malawian aquaculturalists generally have one pond of approximately 300-400 m² in which they polyculture Oreochromis shiranus and Tilapia rendalli, sometimes with Cyprinus carpio. Yields from fish ponds are low (1 t/ha/yr). The major pond input is maize bran, which is used for human and animal food and is scarce during the rainy season.

On-farm bioresource assessments have shown that there are agricultural residues such as maize stover (2.5 t/ha/yr), grasses (>4 t/ha measured at the end of the wet season) and wood ash (400 kg/farm/yr), which could be used as pond inputs. Experiments have demonstrated that application of napier grass and maize bran together can improve fish yields up to 3 t/ha/yr. Wood ash from household cooking fires can improve water fertility and raise pH.

Low-cost technology transfer is accomplished by showing farmers a "basket" of technologies at the research station where they are encouraged to critically assess the available technologies. Farmers who have seen and critically evaluated these technologies are more likely to adopt them. In a farmer survey, 76% of those who had visited the research station were using more than one technology compared with only 32% of a control group. Using the "shopping basket" approach to technology transfer has resulted in rapid adoption of rice-fish culture. This has never been practiced in Malawi before. Farmers achieved rice yields of 2-2.4 t/ha/yr and fish yields of 1.5-2.4 t/ha/yr from rice-fish

ponds. Farmers who usually grow only one crop of rice per year are now starting second crops during the dry season.

Introduction

Aquaculture has not been adopted widely in rural Africa, primarily because the technology has no traditional base in smallholder agriculture. Most rural households operate outside the cash economy, and thus have little expendable income to purchase the feeds and fertilizer that make aquaculture economically viable.

Malawi's population is 8.2 million (NSO 1987), of which 80% are directly involved in agricultural production. The International Service for National Agricultural Research (ISNAR 1982) stated that smallholder farming accounted for 84% of the agricultural GDP. However, only 25% of that contribution entered the cash economy in the early 1980s. Current figures are not available, but demographic and economic indicators suggest there has been little change since ISNAR's report.

Malawi government policy has favored estate development rather than smallholder agriculture, resulting in further limitations on participation in the cash economy (Kydd and Christiansen 1982, Peters and Herrera 1989). Malawi's high population growth (3.7% per annum, NSO 1987) further exacerbates this situation and is leading to a shortfall in food supply among rural communities.

Production of smallholder food crops has been falling since the mid-1970s. This reduction has been due to increasing shortage of arable land. Average per capita landholdings are expected to decline to 0.26 ha by the year 2000 in Malawi (World Bank 1989). With such severe land constraints it will be necessary to use marginal lands and improve the utilization of existing land.

Fish is the major source of animal protein for human consumption (60-70%, Satia 1989) but is quickly becoming a scarce and expensive food commodity in Malawi. Msiska (1985) noted that between 1972 and 1984, per capita consumption of fish fell by 53 %, from 17.9 kg to 9.5 kg per year. Malawi's lake fisheries have reached their productive limit in terms of fish supply (60,000-70,000 t/yr) and cannot meet the demands of a rapidly growing population (Msiska 1985). The Malawi government is now attempting to expand smallholder aquaculture to help relieve the shortfall in fish supplies and raise rural incomes.

The introduction of aquaculture to farmers in Malawi started in the early 1950s but has not been particularly successful. This is reflected in the low production figures for the 1980s of approximately 100 t/yr for the whole country, just 0.1% of capture fisheries production (Balarin 1987).

Kalinga (1991) suggests that lack of capital, suitable fish species and feeds, appropriate management techniques, and extension capacity all contribute to Malawi's poor performance in aquaculture. Balarin (1987) suggests that the lack of an integrated development approach is also a major problem.

Aquaculture projects often fail to address the problems and needs of smallholder and subsistence farmers and too often treat aquaculture as a stand-alone enterprise in the farming system. For example, many aquaculture projects in Malawi have presented farmers with technological packages designed to operate only as an independent commercial operation (GOPA 1987).

With farm sizes of usually less than 1 hectare, many Malawian farmers are operating at, or close to, subsistence and have very low cash incomes. Under these circumstances, they cannot afford

to purchase the formulated feeds and chemical fertilizers that are demanded by commercial aquaculture. Therefore, such technology packages will only be appropriate for a very small, restricted group of households with relatively high incomes.

If aquaculture is to have a wide impact on nutrition, farm incomes, and rehabilitation of resource systems in rural Malawi, it is necessary to have flexible aquaculture technologies that fit into a wide range of traditional farming practices and farm resources.

Aquaculture Research

In 1987, ICLARM, funded by Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ), initiated a farmer-participatory research project with the Malawi Department of Fisheries (FD), the objective being to develop aquaculture technology appropriate for rural Africa (ICLARM and GTZ 1991). The target group of research efforts are rural smallholder farmers with access to, or tenure rights over, water resources.

Studies are directed toward integrating aquaculture technologies into the smallholder maize-based farming systems. This is achieved by continual farmer-researcher interaction throughout the research program, thus enabling researchers to:

- Assess the agroecological resources of farmers and the extent of their traditional agricultural knowledge, thus providing information on the constraints to adoption of aquaculture;

- Develop on-station research to test technologies relevant to rural farmers and their farming systems; and

- Monitor and evaluate, in collaboration with farmers, the performance and impact of new technologies and integrated agriculture-aquaculture models on farming systems.

A report of the ICLARM-GTZ/FD collaborative research program is presented in Costa-Pierce et al. (1991).

On-Farm Bioresources Assessments and Current Status of Aquaculture

A large survey of farmers practicing aquaculture in Zomba District, Southern Malawi, was conducted to establish baseline data on pond sizes, number of ponds per farm, species of fish reared, etc. Table I summarizes this information.

A smaller survey of farmers was carried out to establish cropping and land use patterns. Biomass and production of crop and weed residues were measured wherever possible. Livestock wastes were estimated for some farms, as well as inputs of agricultural residues into fish ponds. Tables 2, 3, and 4 show land use patterns and availability of crop residues.

Data from bioresource assessments established that certain materials were often underutilized and had the potential for use in ponds. These were maize stovers, fallow land grasses, and wood ash from household cooking fires.

TABLE 1 Vital Statistics of 209 Smallholder Fish Ponds on 128 Farms in Zomba District, Malawi

	Quartiles			
	Mean	Median	25 %	75 %
Pond area (m²)	338 (SE=34)	196	105	400
Total area of land under ponds on each farm (m²)	537 (SE=80)	205	96	558

Pond number/farm	1.8 (SE=O. 1)	1	-	-

Total number of hatchery ponds: 36 (17%)

Total number of production ponds: 173 (83%)

For example, maize stover production was 2.5 t/ha/yr, all of which was composted directly into the ground. There were enough stovers on farms for a proportion to be converted to high-quality compost as a pond input. Therefore, one potential research study was to look at the suitability of converting maize stover into a high-quality compost for use as a pond input.

Fallow land grasses and weeds were in relative abundance. The values in Table 4 are end-ofseason biomass, so turnover rates and grass production could be increased by cropping grass regularly for use as a pond input. Edwards et al. (1988) has shown that fish yields can reach as high as 5-6 t/ha/yr with vegetation as a sole pond input.

Availability of grass and its use by most farmers as a pond input for growing Tilapia rendalli (macrophytic feeder) led to studies of grass as a direct feed (Chikafumbwa 1990). The most common food input for fish ponds is "madeya" (maize bran), which is seasonally scarce. Maize bran is also sometimes used as food for humans in periods when maize meal is scarce. Therefore, grass has the potential to be a cheap substitute and possibly a more suitable food source for a macrophytic feeding fish such as T. rendalli.

TABLE 2 Pattern of Land Use Areas (ha) on 10 Smallholdings with Fish Ponds in Zomba District, Malawi

	Mean	Standard Deviation	Range
Holding size	1.6	0.	0.5-3.2
Crop land	1.2 (82%)	0.5	0.5-2.5
Fallow land	0.2 (13 %)	0.2	0-0.6
Total pond area	0.07 (5%)	0.07	0.1-0.2

TABLE 3 Average Production of Maize Residues on Farms with Fish Ponds, April-May 1989

	Local Maize		Hybrid Maize[2]	
	kg/ha/yr	kg/farm	kg/ha/yr	kg/farm
Stovers	2,479	2,552	2,789	3,068
Sheaths	181	172	122	26
Cobs	281	152	485	321
Bran	291	297	660	466

'Sample of 17 farms

[2]Sample of 3 farms

Farmers' ponds are nutrient poor in the Zomba district of Malawi. The main cause is the low nutrient status of the underlying ferrous soils and the resulting acidic waters, which lead to very low fertility (alkalinities 5-10 mg/1). Wood ash is a resource that is discarded in most households and has been demonstrated to improve the pH of pond waters and act as a phosphorus source (Jamu 1990). More than 400 kg wood ash/farm/yr was produced on the few farms that were sampled, and most was unutilized.

In the examples just noted, it is obvious that there are materials on farms that could be used as potential feeds and fertilizers in ponds. These on-farm assessments provide researchers with information that enables them to rank research objectives and also establish personal contact with farmers. This interaction helps sensitize farmers to the research program and the importance of their role in helping researchers to adjust their study objectives.

Farm Management and Integration

Coupled with the resource assessment above, farmers were asked to explain their calendar of agricultural activities and why these activities were organized in a particular way. Figure 1 shows a seasonal calendar for a farmer with a moderate level of integrated farm enterprises, and Figure 2 shows a calendar for a farmer with a high diversity of integration. These calendars enable researchers to see seasonal changes in bioresource management.

TABLE 4 Average Terrestrial Weed Biomass on Farms with Fish Ponds, June-July 1989

	Herbaceous Plants		Grasses	

	kg/ha	kg/farm	kg/ha	kg/farm
Maize fields'	1,128	1,236	120	191
Fallow land²	322	41	4,252	2,516

'Sample of 6 farms

²Sample of 5 farms

A further step in this process is for researchers to encourage farmers to draw pictorial models of their farm systems (Lightfoot and Tuan 1990). These models show the bioresource flows between farm enterprises, thus providing a picture of the dynamics of the system and its level of integration. These pictures allow farmers to visualize their whole farm and see where new enterprises and linkages can improve farm integration, efficiency, and productivity. The process of pictorial modeling is described in a booklet and accompanying video by Lightfoot et al. (1991).
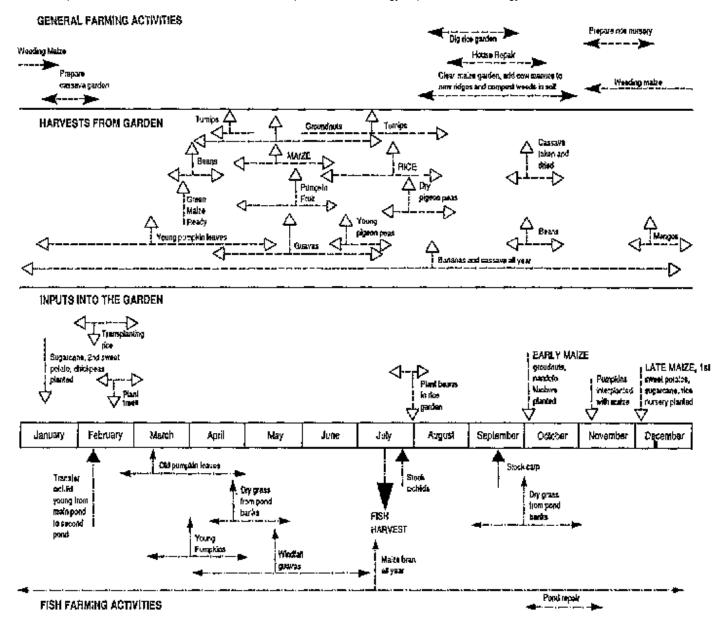
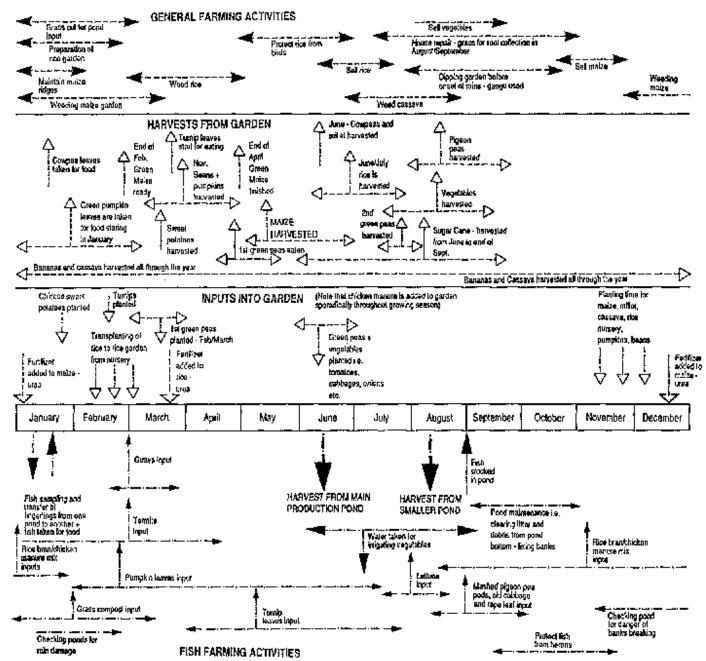FIGURE 1. Farm with high level of crop-pond production

FIGURE 2. Farm with low-level of crop-pond integration

Smallholder Fish Production

Harvest yields of smallholder ponds were assessed to provide baseline data for comparisons with on-station experimental results. Table 5 shows the harvest yields for farmers practicing polyculture, and Table 6 shows the sizes of fish obtained from harvests (Noble and Chimatiro, unpublished). Yields are generally poor and fish small.

Results of On-Station Research

Results of on-station experimentation with on-farm bioresources and other low-cost materials are shown in Table 7. What is clear is that fish yields can be increased significantly using resources already available on most smallholder farms. In addition, farmers could mix resources, depending on their seasonal availability, and raise production well above that of maize bran input alone.

For example, a mix of grass and maize bran raised mean yields from ponds by a factor of 3 (approximately 3 t/ha/yr) compared with farmers ponds (approximately 1 t/ha/yr) using maize bran.

Fish yields from ponds receiving pumpkin leaves (1 t/ha/yr) (Chimatiro and Costa-Pierce 1991) are similar to farmers' ponds. Pumpkin leaves are available when maize bran is not, so it could prove a valuable substitute.

TABLE 5 Harvest Summary for Polyculture of Oreochromis shiranus, Tilapia rendalli, and Cyprinus carpio in 14 Ponds in Zomba District (June-August 1989)

	Oreochromis shiranus	Tilapia rendalli	Cyprinus carpio
Harvest biomass (kg/pond, kg/ha)			
Mean	18 (524)	6 (141)	12 (354)
Median	15 (324)	4 (76)	9 (225)
Range	1-40 (57-2,391)	1-17 (13-558)	4-23 (96-1,551)
Harvest production (kg/halyr)			
Mean	526	154	364
Median	321	94	211
Range	66-1,948	16-574	136-1,264

Mean number of days between harvests: 345 (range: 177-448); mean pond size: 565 m² (range: 70-1,564 m²).

Identification of locally available materials as pond inputs has proved an important and successful element of the research program. Examples shown above indicate how sustainable aquaculture at smallholder levels could develop.

TABLE 6 Growth Summary for Oreochromis shiranus, Tilapia rendalli, and Cyprinus carpio in Polyculture Ponds in Zomba District (June-August 1989)

	Oreochromis shiranus	Tilapia rendalli	Cyprinus carpio
Fish sold (g)			
Mean weight	20.9	26.6	293.1
Median weight	16.4	16.3	275.3
Range	(6-53)	(6-93)	(174-543)
Fish not sold (g)			
Mean weight	5.5	6.2	131.5
Median weight	5.2	5.1	143.2
Range	(1-14)	(1-13)	(52-257)
All fish (g)			
Mean weight	13.9	20.1	238.6
Median weight	9.8	10.7	246.6
Range	(6-36)	(5-57)	(63-543)

Note. The mean weights of each fish species in 16 ponds were averaged to get the overall means, medians, and ranges above. Hence, these figures are showing between-pond variations.

TABLE 7 Mean and Ranges of Net Yields of Fish Ponds, Costs, and Incomes of Fish Farmers in Malawi Using On-Farm Resources (Chikafumbwa et al., Unpublished)

		Mean Yields		Cost of Input		Income
Inputs	Input Rates	(kg/hatyr)	Range	(US$)	(US$)
Napier grass (NG)	100 kg DM/ha/day	1,405	647-2,195	14.58	34.00
Maize bran (MB)	3% MBWD	1,726	406-2,368	2.65	41.77
NO/MB	As above	3,013	2,726-3,299	17.23	82.70
Waste pumpkin leaves*	50 kg DM/ha/day	1,444	1,372-1,616	12.6	35.06
Maize stover compost/FWA**	3% MBWD; 2.5 t/ha	750	710-790	7.38	18.20
Smallholder farmers using MB	When available	NA	400-500	2.65	10.89
Smallholder farmers using MB	When available	951	241-3,336	2.65	23.01

*Cost of waste pumpkin leaves based on labor input to harvest waste leaf **FWA= Fuelwood ash and agricultural limestone combination*

NA=Data not available

MBWD= Mean body weight per day

[1] Cost of fresh fish, 1991 retail prices @ US $1.21

[2] Cost of maize bran @1 US $0.04/kg dry matter @10% moisture

[3] AL= Agricultural limestone @ US $0.04/lcg

[4] FWA (Fuelwood ash) = No cost: a waste resource from household cooking fires

[5] Cost of maize compost based on labor input @US $0.81/day to construct compost heap; purchase of bamboos for pile aeration @US $0.13/bamboo

[6] Napier grass cost based on labor input to cut grass @US $0.81/day

[7] Costs of inputs are per kg/yr per 200 m² pond (2 fish crops/yr; 1 ha pond)

[8] Income is per 200 m² pond (2 fish crops/yr; 1 ha pond)

Other Potential Research Areas

In the current situation of high population densities and land shortage, more marginal land will have to be brought into production by using it for enterprises such as aquaculture. Lightfoot (1990) points out that new ways of utilizing land to help regenerate environments is urgently needed. He suggests that biological diversification of farms and improved nutrient cycling by incorporating aquaculture could help achieve this objective.

Integration of aquaculture on smallholder farms might help to create sustainable, regenerative farming systems (Lightfoot 1990). Most farmers practicing aquaculture in Malawi have vegetable gardens and rice fields adjacent to ponds. It would require very little effort to interlink these enterprises for mutual benefit.

On-station research and demonstrations have been directed to look at the potential of integrating fish with crops (rice, vegetables, maize) and animals (goats, chickens). Malawian farmers also have difficulty harvesting fish. Appropriate harvesting technologies must be suitable to the income and labor resources available to farmers. One research area for focus was harvesting tools and techniques such as reed seine, basket traps, plunge baskets, and recruit removal (Kaunda 1991).

Another important aspect that has led to low yields is the poor growth performance of the two major cultivated species, O. shiranus and T. rendalli. Research studies have started on utilization of the large Lake Malawi tilapias, particularly O. karongae ("chambo") and catfishes, such as Bathyclarius sp. (Msiska 1991).

The research program is attempting to develop new indigenous systems of aquaculture based on the existing farming system and resource base of the Malawian rural farmer. The combination of new inputs, new fish species, and new systems of integration based on local resources has the potential to produce a more productive, indigenous, and sustainable aquaculture for smallholder farmers.

Farmer Participatory Research

A major problem facing any research project attempting to improve smallholder farming systems is encouraging farmers to adopt new enterprises and modify and integrate existing ones. The ICLARM/FD project has avoided presenting technology packages to farmers. African agroecosystems are highly complex and no one enterprise or technology is going to be applicable over a wide range of farming systems. To ensure that research priorities meet the farmer's agenda, the farmer must be able to assess the technologies and systems being designed by researchers.

Exposure of Farmers to New Technologies

Part of the ICLARM/FD program has been focused on the methodology required to engender farmer participation in the research. One approach has been to encourage farmers to visit and assess on-station experiments and comment on the range of aquaculture options on offer. Farmers are given freedom to express their feelings about the technologies and make suggestions for new lines of research, or modifications to existing research. Farmers are able to explain to project personnel which technologies are most appropriate for their farming system.

On-station open days with farmers are organized with a workshop where farmers lead the discussion and help researchers to reformulate research objectives. This occurs after the farmers have viewed a "basket" of technologies on offer. Showing respect for farmers' opinions and knowledge helps to win their confidence and makes it easier for both researchers and farmers to work together to develop appropriate aquaculture technologies and systems.

The effect of open days on technology research and transfer has been documented by Noble and Rashidi (1990). In May 1990, the first open day was held at the National Aquaculture Center (NAC) with 29 farmers. Six months later, 54 farmers were interviewed: 29 who had been to the open day, and 25 who had not, and 76% of the former were operating more than one technology in their ponds, but only 32% of the latter. Exposure to technologies and a variety of pond management strategies enables farmers to pick options that suit their local circumstances.

However, the open days are only one aspect of farmer-researcher interaction. Farm visits to evaluate bioresources, technology performance, and impact are all part of an on-going dynamic, which has led farmers to adopt new aquaculture technologies more readily and new entrants coming into aquaculture.

Rice-fish Integration

A particularly effective example of this type of process and farmer-researcher interaction is with rice-fsh integration. In December 1990, farmers were shown an experimental rice-fish pond at the NAC. Until that time, farmers had never seen rice and fish grown together. They were shown harvests of both crops on the same day. At a workshop to discuss rice-fish, the farmers were excited by the idea, but heavily critical of the experimental setup. The researchers encouraged them to draw their own designs (Figures 3a, 3b, and 4). These were very sophisticated and demonstrated that farmers were capable of contributing effective ideas even in an area where they had no experience.

Farmers quickly realized that the most effective arrangement was to be able to easily decouple rice and fish and have an efficient means of concentrating fish in deeper waters away from rice. They had come, in one day of exposure, to the same conclusions reported by dela Cruz (1990) in a large collaborative research program by IRRI and ICLARM in the Philippines.

In response to farmers' criticisms and suggestions, a second rice-fsh pond has been built to their design at NAC. This incorporation of farmers' ideas in the on station research program has helped to forge a strong collaborative link between researchers and farmers.

In February 1991, a field survey showed that of the 17 farmers that came to the rice-fish day, eight (47%) had started rice-fsh ponds. Yields were good (ranges: 2.4-4 t/ha/yr for rice, 1.5-2.4 t/ha/yr for fish) and farmers stated they were higher than normally expected. Nutrient-rich pond muds and reduction of water and weed constraints probably contributed to the high rice yields. Four farmers were so impressed that they have started a dry season crop of rice.

We are seeing the evolution of an indigenous rice-fish farming system. Farmers have adopted a technology that is new, but very relevant to their farming environment. They have modified the technology to make it more efficient and started to operate new management strategies that have never before been tried (i.e., two crops of rice per year).

It is particularly exciting that farmers who have not been to open days at the NAC are starting to adopt indigenous technologies that have been developed by farmer-researcher interaction. Some of the new rice-fish farmers are in a large rice-growing area where farmer-to-farmer diffusion of technology can occur rapidly. This is resulting in new entrants to aquaculture through rice-fish integration as well as existing fish farmers adopting this new system for their ponds.

What is evident is that the success of the research program with regard to rice-fish has been aided by the sensitivity and understanding researchers have shown for what is feasible in agriculture-aquaculture integration on Malawian farms. The researchers presented these ideas to farmers and allowed them to decide the applicability of rice-fish integration to their farming situation.
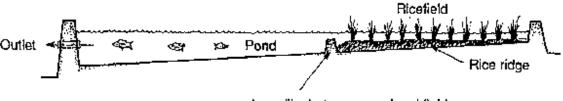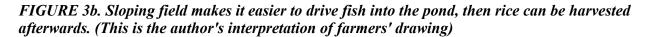

FIGURE 3a. Malawian farmers' drawing of a possible rice-fish arrangement (two farmers composed the drawing)

FIGURE 3b. Sloping field makes it easier to drive fish into the pond, then rice can be harvested afterwards. (This is the author's interpretation of farmers' drawing)

Monitoring and impact assessment of rice-fish and use of other technologies by farmers is now being carried out. Farmers are modifying technologies they have seen at the NAC to suit their own circumstances. Part of the on-farm research program will be to determine if such changes are effective in leading to sustainable aquaculture systems and whether they have wider applicability across the broad spectrum of Malawian farming systems.
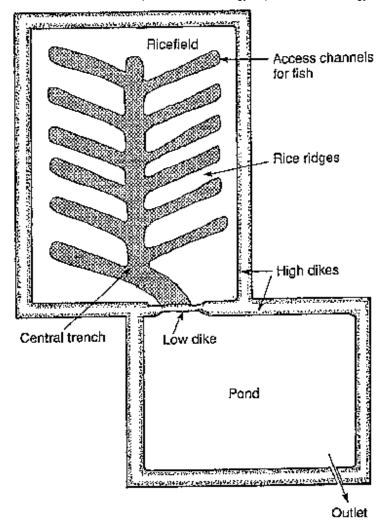
FIGURE 4. Rice-pond arrangement designed by two farmers. Rice field is sloped towards central trench and trench slopes toward pond.

Conclusion

The core of the ICLARM/FD research program is farmer-participation, emphasizing on-station research and implementing on-farm experiments. Lightfoot (1990, 1991) points out that this is essential if sustainable aquaculture systems are to be developed.

As most farmers in Malawi operate their smallholdings at, or close to, subsistence level, farmer participation is essential for aquaculture development to be fully integrated into the farming system. The diversity of farming strategies and agroecosystems in Malawi precludes the use of general aquaculture packages. Success in aquaculture development will be achieved by taking a flexible, evolutionary approach to production of appropriate technology for smallholders. This can be achieved only by farmer collaboration in modifying new and existing aquaculture systems to suit a variety of local farming conditions.

Farmer participation in the research program has many facets ranging from farmer visits to on-station experiments, to farmer workshops both on-station and on-farm, and farmer-researcher experiments on farm. This dynamic interchange helps to ensure that research objectives are in line with the needs of farmers.

It is hoped that this farmer-first approach in the research program will lead to indigenous sustainable aquaculture systems for Africa that not only produce fish, but enhance the productivity of the whole farming system.

Acknowledgments

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