POND DYNAMICS/AQUACULTURE COLLABORATIVE RESEARCH SUPPORT PROGRAM
RESEARCH REPORTS
SUSTAINABLE AQUACULTURE FOR A SECURE FUTURE

Small-Scale Fish Farming in Rwanda: Economic Characteristics

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Abstract

A survey was conducted of 156 cooperative and 111 individual Rwandan fish farmers to estimate the costs and returns of aquacultural and agricultural crops. Enterprise budgets were developed for both individually and cooperatively produced fish, sweet potatoes, Irish potatoes, cassava, taro, sorghum, maize, peas, beans, soybeans, peanuts, rice, and cabbage. With the exception of Irish potatoes, all enterprises showed positive income above variable costs and positive net returns to land, labor, and management. Fish production yielded the highest income above variable costs and the highest net returns if fingerlings could be sold. If only food fish could be sold, cabbage was the most profitable crop. Sweet potatoes produced the highest yield of carbohydrates and soybeans were the least expensive source of protein. This study demonstrated that the cash income per unit of land generated by fish production is superior to other crops raised in the *marais* in Rwanda. While aquaculture is often considered a source of animal protein for household consumption, a high potential also exists for cash income generation.

Introduction

Small-scale fish farming is reported to be a primary source of animal protein to nutritionally deficient nations. The main objectives of small-scale fish farming in developing nations are to 1) supply protein-rich food to rural people at reasonable prices and 2) provide limited, steady income and employment (Belsare, 1986). The Government of Rwanda has placed a high priority on national food self-sufficiency and regional market integration (Ministère du Plan, 1983).

Surveys conducted in Rwanda revealed that many small-scale fish farmers consider fish to be a cash crop. Findings by Engle et al. (1993) indicated that fish farming provides cash to the family and supplements the diet of the Rwandan farmer. Molnar et al. (1991) and Engle et al. (1993) both found that fish production was the main cash crop for over 50% of cooperative members and private pond-holders.

Over 24,000 Rwandan farmers practice and benefit from subsistence fish farming (Mpawenimana, 1991). As of 1991, there were nearly 3,900 fish ponds in Rwanda, covering approximately 130 ha. These ponds yielded an estimated annual production of 237 metric tons.

Small-scale fish farming in Rwanda may also be viewed as a means to improve food security. Daily animal protein intake in Rwanda was estimated at 2.1 g per capita (Wilcock and Ndoreyaho, 1986); however, the Ministry of Agriculture (MINAGRI, 1987) reported that an adequate diet requires 5.9 g of animal protein daily. Fish contains high quality protein, vitamins, minerals, and other nutrients important for human health and growth (Chatfield, 1954; Latham, 1965). A combination of fish and a lower quality protein meets the proven requirements of an adequate diet. Nutrition experts agree that fish, with the addition of a variety of vegetable products, constitutes a completely balanced diet. A comparison of the protein production of fish farming with the protein production of other agricultural enterprises would be useful to both farmers and policymakers; however, no data are available. With the current dilemma of declining land productivity, an escalating population, and frequent food shortages, protein production deserves particular attention.

The *marais* or valley lowlands of Rwanda, where fish farming is practiced, are considered the only source of agricultural lands available for the introduction of new technologies such as fish culture (Sikkens and Steenhuis, 1988). Given that the average farm size per family is only about 0.5 ha, fish culture activities are likely to compete with other farming activities for one of Rwanda's most limited resources —land. Fish culture costs and benefits must be measured against other competing means of protein production to assess which makes best use of scarce resources.

Abundant examples of economically feasible, small-scale fish culture ponds in Thailand and China have been reported (Rappaport and Sarig, 1978; Sin and Cheng, 1976). A number of sources (AIT, 1986; Cruz and Hopkins, 1982) have identified small-scale aquaculture in the Philippines and China as a way of improving the standard of living of small-scale farmers. Integrated, small-scale fish farming has played a major role in boosting the economy of some villages in India (Belsare, 1986) and examples from Central Europe have shown that small-scale, integrated fish farming can be highly profitable (World Bank, 1989).

Aquaculture profitability is commonly measured through an analysis of the costs and revenues of the enterprise (Smith and Peterson, 1982). Engle and Hatch (1986) and Hatch and Engle (1987) used financial analytical techniques to show that Panama's resource-limited farmers benefited from the adoption of fish farming. Through the development of enterprise budgets, Hishamunda and Moehl (1989) demonstrated that Rwandan aquaculture, in correctly managed ponds, is a profitable activity that competes favorably with red bean, sweet potato, and rice production. Moehl (1993) used enterprise budgets to compare the profitability of four levels of fish production in Rwanda.

The specific objectives of this study were to 1) compare net returns of fish production with net returns of crops commonly produced in the Rwandan *marais* and 2) evaluate production alternatives in terms of their net contributions to animal protein production.

Methods and Materials

Study Area and Sample

The study covered 56 of the 59 communes (similar to counties in US) registered with the Rwanda National Fish Culture Service (SPN). These communes stretched over 10 of the 11 prefectures (similar to states in US) of the country and covered all fish farming regions. Fish farmers registered with the Rwanda SPN at the time of the survey constituted the sampling universe, which consisted of 1250 cooperative and 1,150 individual farmers.

A random sample was drawn using the cluster sampling technique (Weisberg et al., 1989). During the first stage of sampling, to ensure that data on fish yields were collected, extension agents were contacted to confirm that the farmers chosen for the study had completed a minimum of one fish-pond harvest. Respondents who had not drained their ponds were not surveyed and a different respondent was chosen to participate in the survey. The final sample included three cooperative and two individual farms in each commune covered by the study.

A total of 267 respondents (111 individual farmers and 156 cooperative farmers) represented an overall completion rate of 95%. Non-respondents claimed that they either did not have time to take part in the survey or did not have the information requested.

All references to prices are cited in the text in Rwandan francs (RF), the unit of national currency. In 1991, US$1 was equal to RF145.

Survey Instrument

The survey instrument, which appears in CRSP Research Report 98-124a, “Small-Scale Fish Farming in Rwanda: Data Report” (Hishamunda et al., 1998), was developed in English and translated into Kinyarwanda, the national language of Rwanda. It was divided into several sections, including farm family characteristics (age, training level, marital status), farm status (land tenure and allocation), farm location and characteristics (size, equipment, and facilities), and farm management. Livestock and associated production level data were collected along with economic information regarding off-farm employment and income, distribution and use of farm output, market outlets, prices, and cash farm income. The survey instrument used both closed- and open-ended questions depending on the type of information desired.

Direct personal interviews were conducted at farmers’ residences at appointed times or at the farmer’s convenience from 5 September to 18 September 1991. Approximately one to two hours were spent with each interviewee. Survey enumerators were Rwandan aquacultural extension agents who were in frequent contact with farmers and thus were knowledgeable about farming practices.

Secondary Data

Data collected through direct interviews were supplemented with individual pond records kept by extension agents.

Data were checked for entry and recording errors, missing data, and consistency before analysis. Entry and recording errors were amended. Comparisons between answers to related questions enabled checking for consistency. Missing, inconsistent, or unreliable data that did not meet the criteria outlined in the companion data report (Hishamunda et al., 1998) were dropped from the analysis (Cochran, 1977; Weisberg et al., 1989; and Williams, 1993).

Analysis

Cross-tabulation techniques were used to summarize survey results and to describe farming systems in the Rwandan *marais*. Two-way and three-way frequency tables were generated using the SAS-PC (SAS Institute, Inc., 1985) tabulation program. For some pairs of variables, the chi-square (X^2) test was run to check for the existence and strength of relationships between variables. Cooperative and individual farmers were compared and the 5% significance level was employed to make statistical inferences.

Crop enterprise budgets were developed based on the survey data. Net returns to land and management, with and without family labor charges, were calculated. Relative nutritional benefits of crops cultivated were calculated by converting crop yields to grams of protein and carbohydrates produced per are (1 are = 100 m^2), as outlined in the companion data report (Hishamunda et al., 1998).

Results

Fish Pond Management

The majority of farmers interviewed (98%) raised Nile tilapia (*Oreochromis niloticus*) in monoculture. Other fish species raised in either mono- or polyculture included *O. macrochir*, and *Tilapia rendalli*. Common carp (*Cyprinus carpio*) were grown only in polyculture with *O. macrochir*. The mean overall stocking density was 84 fish are^{-1}.

Farmers harvested ponds an average of once per year, generally 11 months post-stocking. The overall average weight of fish at harvest was 173 grams. An overall mean yield of 16 kg fish $are^{-1}yr^{-1}$ was obtained by farmers. The minimum annual yield (1 kg fish $are^{-1}yr^{-1}$) was recorded in individually owned ponds while the maximum annual yield (49 kg fish $are^{-1}yr^{-1}$) was obtained from cooperatively owned ponds.

Ninety-two percent of all the farmers surveyed consumed part of the fish produced and only 8% of farmers never consumed fish produced in their ponds.

For all respondents, 56% of the fish harvested was sold and 28% was consumed by producers. Small quantities were given away (11%) or used to restock ponds (6%). This indicates that farmers tended to sell a higher percentage of fish than they consumed. Thus, the primary goal of fish production was to earn revenue from products sold. Meeting nutritional needs of the family was a secondary objective for producing fish. Previous studies reported that 65% of the harvest was marketed and 35% was consumed by producers (Hishamunda and Moehl, 1989). The harvest distribution pattern was the same for cooperative and individual farmers.

Costs and Returns

Labor

Labor activities that figured into the enterprise budget analysis included pond construction, adding water to ponds, plugging leaks in levees, pulling weeds, cutting grass, mixing compost into ponds, applying feed and manure, and watching ponds. Frequencies of specific labor activities are reported in the companion data report (Hishamunda et al., 1998) and overall labor costs are summarized in Tables 1 and 2 of this report. All fish ponds were manually constructed and 74% of farmers exclusively used family labor. Pond construction costs reported by respondents ranged from Rwandan francs (RF) 2,000 to 25,600 with a mean of RF7,435 per are. Per-are cost was RF7,807 for cooperatively built ponds and RF6,228 for individually built ponds.

Costs

Sixty-four percent of the farmers bought fingerlings from either government fish stations or private producers to stock in ponds. Six percent of the farmers received them free from producers and 30% stocked fingerlings produced in their own ponds. The average price of tilapia fingerlings (*O. niloticus*) was RF330 per 100 fingerlings for all farmers surveyed.

Eighty percent of the farmers did not feed fish supplemental feed other than compost during the production cycle studied. Almost 87% of the cooperative farmers and nearly 93% of the individual farmers applied fertilizers. Fertilizers applied to ponds were primarily animal and green manures and composted household wastes. The high percentage of farmers who fertilized ponds and the low percentage of farmers who fed fish indicate that fish may have consumed almost solely natural foods in the pond. These natural foods, however, may have included compost ingredients.

Returns

Information on use of harvested fish, unit of sale, market categories, cash and credit received for fish sold, and income allocation is included in the companion data report (Hishamunda et al., 1998).

The overall proportion of marketable fish (calculated as the weight of fish above fingerling size/total net harvest) ranged from 40 to 100% and averaged 82% for all respondents. Responses from individual and cooperative farmers were similar. Annual net yields averaged 16 kg $are^{-1}yr^{-1}$.

A 77% overall recovery rate (number of fingerlings stocked/number of fingerling-size fish harvested) was recorded by farmers. Some of the farmers only harvested 19% of the fish stocked, while others had a 100% recovery rate. The maximum recovery rate (100%) was noted for both cooperatively and individually owned ponds.

The overall mean price of food fish was RF147 kg^{-1}, with a range of RF100 kg^{-1} to RF257 kg^{-1}.

Use of Fish Harvested

It was determined from all the farmers surveyed that 61% of food-sized (marketable) fish were sold, 31% were consumed by producers, and 8% were given away. It is important to note that individual farmers never sold or gave away all the food fish harvested—at least 3% of food fish was consumed at home. Given that many Rwandan subsistence farmers may consume meat only twice per year, the fact that they all kept some fish for home consumption is important. This suggests that fulfilling both the cash income and food needs of the family is important to the farmer.

Table 1. Annual enterprise budget for fish production of a one-are, individually managed pond in Rwanda, 1991.

Item	Quantity	Price or Cost/Unit (RF[a])	Cash Cost or Value (RF)
1. GROSS RECEIPTS			
Food Fish	13.7 kg	149.00	2,041
Fingerlings	350.6 fish	3.90	1,367
Total Receipts			**3,408**
2. VARIABLE COSTS			
Fingerlings	83.0 fish	3.90	324
Feed	0.0 kg	0.00	0
Compost	0.0 kg	0.00	0
Interest on Variable Costs	216.9	0.06	13
Total Variable Costs			**337**
3. INCOME ABOVE VARIABLE COSTS			**3,071**
4. FIXED COSTS			
Depreciation on Pond		298.0	298
Depreciation on Equipment		166.4	166
Total Fixed Cost			**464**
5. TOTAL COSTS			**801**
6. NET RETURNS TO LAND, LABOR, AND MANAGEMENT			**2,607**
7. FAMILY LABOR			
Feeding	5.6 p-d[b]	100.0	564
Composting	6.1 p-d	100.0	612
Water Regulation	0.8 p-d	100.0	84
Weed Control	1.1 p-d	100.0	108
Maintenance	33.4 p-d	100.0	3,336
Harvesting	7.3 p-d	100.0	732
Marketing	1.7 p-d	100.0	168
Other	6.2 p-d	100.0	624
Total Family Labor	62.3 p-d	100.0	**6,228**
8. NET RETURNS TO LAND AND MANAGEMENT			**-3,621**

[a] US$1 = RF145.
[b] p-d = person-day.

Table 2. Annual enterprise budget for fish production of a one-are, cooperatively managed pond in Rwanda, 1991.

Item	Quantity	Price or Cost/Unit (RF[a])	Cash Cost or Value (RF)
1. GROSS RECEIPTS			
Food Fish	12.9 kg	145.00	1,868
Fingerlings	377.6 fish	3.20	1,208
Total Receipts			**3,076**
2. VARIABLE COSTS			
Fingerlings	84.0 fish	3.20	269
Feed	0.0 kg	0.00	0
Compost	0.0 kg	0.00	0
Interest on Variable Costs	172.0	0.06	10
Total Variable Costs			**279**
3. INCOME ABOVE VARIABLE COSTS			**2,797**
4. FIXED COSTS			
Depreciation on Pond		390.6	391
Depreciation on Equipment		217.3	217
Total Fixed Costs			**608**
5. TOTAL COSTS			**887**
6. NET RETURNS TO LAND, LABOR, AND MANAGEMENT			**2,189**
7. FAMILY LABOR			
Feeding	11.9 p-d[b]	100.0	1,188
Composting	17.2 p-d	100.0	1,716
Water Regulation	1.4 p-d	100.0	144
Weed Control	1.1 p-d	100.0	108
Maintenance	43.4 p-d	100.0	4,344
Harvesting	11.5 p-d	100.0	1,152
Marketing	4.6 p-d	100.0	456
Other	13.0 p-d	100.0	1,296
Total Family Labor	104.0 p-d	100.0	**10,404**
8. NET RETURNS TO LAND AND MANAGEMENT			**-8,215**

[a] US$1 = RF145.
[b] p-d = person-day.

Household Allocation of Income from Fish Sales

Income from fish farming was re-invested in fish culture, used for other agricultural activities, spent for school fees for children, allocated to household goods, budgeted to meet other needs, and saved in bank accounts. Other needs included paying taxes, purchasing medication, and buying hillside land and livestock.

Household goods and services absorbed the highest percentage (46%) of fish culture income for all respondents. Re-investment in fish culture (23%) was the second largest item to absorb income, followed by school fees (13%), savings (9%), agricultural expenditures (5%), and miscellaneous needs (3%).

There is no statistical difference between how respondents of cooperative and individual farms spent their fish culture income ($p > .05$); however, cooperative farmers saved 16% of their income, while individual farmers saved only 2% of their income. This suggests that individual farmers may be more flexible in the use of their income than cooperative farmers. When private producers choose to consume their revenue, they do so. Cooperatives are organized to serve the interests of members. Given the small pond area of each cooperative member (0.1 are $member^{-1}$) and the volume of fish harvested from their ponds per harvest, cooperative farms cannot generate revenue sufficient for each cooperative member to put some into savings. Because cooperative farm income is shared, farmers must rely on their savings to accumulate a substantial amount of money to meet expenses.

<u>Enterprise Budgets</u>

Annual costs and returns for fish production of individually and cooperatively managed ponds are presented in Tables 1 and 2. Fish ponds generated more gross revenue from food fish than from fingerlings, although revenue from fingerlings constituted 40% of the total gross revenue for individually managed ponds and 39% for cooperatively managed ponds.

Fingerling cost was the only cash variable cost in fish production. Survey results revealed that most fish farmers did not feed and that labor associated with composting was performed by the pond operator and family members.

Net returns to land, labor, and management were higher for individually managed ponds than for cooperatively managed ponds. Individual pond managers produced higher yields due likely to greater quantities of compost applied to fish ponds.

All enterprises, with the exception of Irish potatoes, showed positive income above variable costs and positive net returns to land, labor, and management (Tables 3 and 4). Fish farming, followed by the cabbage enterprise, yielded the highest income above variable costs along with the highest net returns to land, labor, and management.

For individually managed farms, Irish potatoes had the second highest gross revenue of alternative crops (after cabbage), but also had the highest variable cost. After cabbage, peanuts were most profitable, followed by rice, sweet potatoes, maize, taro, soybeans, beans, sorghum, Irish potatoes, cassava, and sweet peas. Irish potatoes and cassava required the greatest amounts of operating capital.

For cooperatively managed operations, cabbage was still most profitable (after fish), followed by beans, maize, cassava, soybeans, taro, sorghum, and sweet potatoes. The Irish potato enterprise was not profitable. The difference in rankings of profitability between individually and cooperatively managed operations was due to changes in use of production inputs and yields.

Gross revenues from fish production were higher than from cabbage production. Cabbage production, the second most profitable enterprise, had greater variable cost, which included the purchase of compost, pesticides, and inorganic fertilizers. Fish production's higher revenues coupled with lower variable costs resulted in higher profits as compared with cabbage.

If opportunity costs were charged for family labor in the analysis, the cabbage enterprise, managed by individual farmers, was the only profitable enterprise. Cooperative fish farming yielded the lowest (highest negative) net returns to land and management because labor was allocated inefficiently. It was found that 43 person-days were used to maintain a one-are fish pond, 11.5 person-days were allocated to harvest 16 kg of fish, and 4.6 person-days were used to market 16 kg of fish. This situation indicates a surplus of farm labor signifying a condition of disguised unemployment. Available

Table 3. Annual cost and returns in RF[a] for *marais* agricultural enterprises of individual fish farmers, Rwanda, 1991.

Crop	Gross Receipts	Variable Cost	Income Above Variable Cost	Total Cost	Net Returns to Land, Labor, and Management	Family Labor	Net Returns to Land and Management
Fish	3,408	337	3,071	801	2,607	6,228	-3,621
Sweet potato	1,471	388	1,083	826	645	2,265	-1,620
Irish potato	2,103	1,789	313	1,895	207	2,113	-1,906
Cassava	1,160	955	205	1,031	129	1,810	-1,681
Taro	960	403	557	600	360	1,960	-1,600
Sorghum	540	154	386	332	208	1,350	-1,142
Maize	925	424	501	515	410	1,884	-1,474
Sweet peas	400	302	98	302	98	440	-342
Beans	920	414	506	690	230	1,530	-1,300
Soybeans	864	412	452	533	331	1,340	-1,009
Peanuts	1,968	148	1,820	148	1,820	2,170	-350
Rice	1,325	366	959	369	956	1,530	-574
Cabbage	3,120	551	2,569	611	2,509	1,320	1,189

[a] US$1 = RF145.

Table 4. Annual cost and returns in RF[a] for *marais* agricultural enterprises of cooperative fish farmers, Rwanda, 1991.

Crop	Gross Receipts	Variable Cost	Income Above Variable Cost	Total Cost	Net Returns to Land, Labor, and Management	Family Labor	Net Returns to Land and Management
Fish	3,076	279	2,797	887	2,189	10,404	-8,215
Sweet potato	1,294	520	774	1,093	201	5,972	-5,771
Irish potato	1,275	1,607	-332	1,745	-470	6,260	-6,730
Cassava	1,080	365	715	464	616	7,190	-6,574
Taro	855	288	567	545	310	7,140	-6,830
Sorghum	810	325	485	502	308	4,870	-4,562
Maize	1,175	407	768	525	650	5,220	-4,570
Sweet peas	†	†	†	†	†	†	†
Beans	1,360	393	967	531	829	5,370	-4,541
Soybeans	1,193	674	518	832	360	4,190	-3,830
Peanuts	†	†	†	†	†	†	†
Rice	†	†	†	†	†	†	†
Cabbage	2,380	429	1,951	508	1,872	7,570	-5,698

[a] US$1 = RF145.
† Cooperative farmers did not raise sweet peas, peanuts, or rice.

Table 5. Average annual quantity of protein, carbohydrates, and energy per *marais* farm activity in Rwanda, 1991.

Crop	**Protein** (kg $are^{-1}yr^{-1}$)			**Carbohydrates** (kg $are^{-1}yr^{-1}$)			**Energy** (kcal $are^{-1}yr^{-1}$)		
	All	*Coop.*[a]	*Ind.*[b]	*All*	*Coop.*	*Ind.*	*All*	*Coop.*	*Ind.*
Fish	2.90	2.86	2.96	0	0	0	15,330	15,120	15,640
Sweet potato	1.98	1.84	2.10	35.93	33.55	38.25	149,376	139,491	159,015
Irish potato	1.28	1.01	1.67	18.30	14.39	23.83	61,796	48,575	80,461
Cassava	0.30	0.28	0.30	21.51	20.35	21.75	26,190	24,788	26,489
Taro	0.84	0.79	0.89	15.74	14.73	16.61	47,823	44,772	50,471
Sorghum	1.51	1.96	1.26	15.00	19.46	12.55	64,190	83,269	53,697
Maize	3.47	3.99	3.10	29.03	33.08	25.95	131,846	150,256	117,879
Sweet peas	1.09	†	1.09	3.04	†	3.04	16,651	†	16,651
Beans	5.20	6.66	4.51	4.39	5.65	3.82	80,164	103,064	69,754
Soybeans	7.02	8.24	5.96	4.52	5.30	3.84	82,873	97,266	70,424
Peanuts	1.92	†	1.92	2.78	†	2.78	45,491	†	45,591
Rice	2.11	†	2.11	40.81	†	40.81	109,710	†	109,710
Cabbage	2.08	1.78	2.34	5.56	4.75	6.24	3,194	2,734	3,586

[a] Cooperative farmers.
[b] Individual farmers.
† Cooperative farmers did not raise sweet peas, peanuts, or rice.

Table 6. Cost of one kilogram of protein by enterprise in Rwanda, 1991.

Crop	**Protein Cost** (RF[a]/kg) (Protein Efficiency Ratio Not Considered)				**Protein Cost** (RF/kg) (Protein Efficiency Ratio Considered)			
	Cooperatives		*Individuals*		*Cooperatives*		*Individuals*	
	w/out labor	with labor	w/out labor	with labor	w/out labor	with labor	w/out labor	with labor
Fish	310	3,941	270	2,372	87	1,110	76	668
Sweet Potato	592	3,829	393	1,469	*	*	*	*
Irish Potato	1,733	7,949	1,136	2,403	*	*	*	*
Cassava	1,657	27,336	3,448	9,502	*	*	*	*
Taro	692	9,753	676	2,883	*	*	*	*
Sorghum	256	2,741	263	1,331	144	1,540	148	748
Maize	131	1,438	166	773	117	1,284	148	690
Sweet peas	†	†	276	678	†	†	178	432
Beans	80	886	153	493	54	599	103	333
Soybeans	101	610	89	314	45	263	38	135
Peanuts	†	†	77	1,205	†	†	47	730
Rice	†	†	174	898	†	†	80	412
Cabbage	285	4,531	261	826	*	*	*	*

[a] US$1 = RF145.
† Cooperative farmers did not raise sweet peas, peanuts, or rice.
* Protein efficiency ratio unknown.

work tasks are divided among labor resources such that all individuals seem fully employed.

Nutritional Value

In Rwanda, 37% of the total population consumes fewer calories than the minimum requirement, and populations with caloric deficiencies in some regions are as high as 82% (World Bank, 1989). In terms of carbohydrates, sweet potatoes produced the highest yield (36 kg $are^{-1}yr^{-1}$) (Table 5). Fish does not contain sugars and starches (carbohydrates). Maize production yielded the highest amount of energy (131,846 kcal $are^{-1}yr^{-1}$). The lowest quantity of energy (3,194 kcal $are^{-1}yr^{-1}$) was obtained from the cabbage enterprise, with fish farming yielding the second lowest value (15,330 kcal $are^{-1}yr^{-1}$), due to the low fat and carbohydrate content of fish.

If opportunity costs for family labor were removed from the analysis, the least expensive source of protein was peanuts (RF77 kg^{-1}) produced by individual farmers (Table 6). The cost of fish protein (RF270 kg^{-1}) was over three times higher than the cost of peanut protein. Beans were the least expensive source of protein (RF80 kg^{-1}) for individual farmers, and fish ranked sixth.

When the opportunity cost of family labor was factored into the analysis, soybeans emerged as the most cost-effective method to produce protein for both groups of producers. A kilogram of soybean protein cost cooperatives an average of RF610, while it cost individual farmers RF314. The production cost of one kilogram of fish protein was RF3,941 for cooperatives and RF2,372 for individual producers.

When the quality of protein was incorporated in the analysis, soybeans still remained the least expensive source of protein. One kilogram of soybean protein cost individual farmers RF38 without the opportunity cost of family labor included in the analysis, and RF135 with family labor costs included. For cooperatives, costs were RF45 kg^{-1} without labor and RF263 kg^{-1} with labor costs. Peanuts were the second least expensive source of protein for individual producers—peanut protein cost RF47 kg^{-1} without family labor and RF730 kg^{-1} with family labor, valued at RF100 day^{-1}, included in the analysis. Fish ranked the third least expensive protein for both individual farmers (RF76 kg^{-1}) and cooperative farmers (RF87 kg^{-1}) when the value of family labor was not included in the analysis. When family labor was included in the analysis, the fish enterprise ranked the fifth least expensive protein source (RF668 kg^{-1}).

The raw data used to prepare the enterprise budgets and food value comparisons in this report are presented in the companion publication (Hishamunda et al., 1998). That report also includes additional information collected by this survey, secondary data which were used in this study, and the survey instrument itself.

Conclusions

The enterprise budget analysis showed that: 1) fish production yielded the highest net returns to land, labor, and management; 2) sweet potatoes produced the highest yield of carbohydrates; and 3) soybeans were the least expensive source of protein. These results explain why fish is used mostly as a source of cash income, while sweet potatoes remain the major staple source of carbohydrates for household consumption.

The results of this study demonstrate that fish culture is a superior production system in terms of cash income per unit of land when compared with other crops raised in the *marais* in Rwanda. Prevailing thought considers subsistence aquaculture to be primarily a source of animal protein for household consumption; however, in the case of Rwanda, fish production resulted in higher net returns to land, labor, and management when compared with other crops. This may explain why Rwandan farmers sold over half of their fish produced. Government and international donor policy related to aquaculture should consider the importance of fish farming as a cash income-generating enterprise for small-scale farmers in Rwanda. In cash-poor, rural areas of Rwanda, fish farming income can be used to rent or purchase additional land, improve health and nutrition through the purchase of additional food and medicine, and further enhance community development through the payment of school fees. While it was beyond the scope of this study to estimate this type of economic multiplier, the potential for economic development should be recognized.

Acknowledgments

Research supported by USAID Grant No. 5053-G-00-0077-00, Project Number 936-5053 to the University of Arkansas at Pine Bluff. We thank Karen Veverica and Pélagie Nyirahibimana for encouragement and support during the survey pre-test and implementation. We thank Drs. Pierre-Justin Kouka and Peter Perschbacher of the University of Arkansas at Pine Bluff and Curtis Jolly and Karen Veverica of Auburn University for helpful suggestions and comments.

Literature Cited

AIT (Asian Institute of Technology), 1986. Buffalo/Fish and Duck/Fish Integrated Systems for Small-Scale Farmers at Family Level: AIT Research Report No. 198. Asian Institute of Technology, Bangkok, Thailand, 48 pp.

Belsare, D.K., 1986. Tropical Fish Farming. Environmental Publications, Karad, India, 160 pp.

Chatfield, C., 1954. Food Composition Tables—Minerals and Vitamins for International Use. FAO Nutritional Studies No. 11. Food and Agriculture Organization of the United Nations, Rome, 56 pp.

Cochran, W.G., 1977. Sampling Techniques. John Wiley and Sons, Inc., South Orleans, Massachusetts, 428 pp.

Cruz, E.M. and K.D. Hopkins, 1982. ICLARM-CLSU Integrated Animal-Fish Farming Project: Final Report. ICLARM Technical Report No. 5. International Center for Living Aquatic Resources Management, Manila, Philippines, 96 pp.

Engle, C.R., M. Brewster, and F. Hitayezu, 1993. An economic analysis of fish production in a subsistence agricultural economy: the case of Rwanda. Journal of Aquaculture in the Tropics, 8:151-165.

Engle, C.R. and L.U. Hatch, 1986. Cooperatively-managed rural Panamanian fish ponds: the integrated approach. In: L.L Lovshin, N.B. Schwartz, V.G. Castillo, C.R. Engle and L.U. Hatch (Editors), Alabama Agricultural Experiment Station: Research and Development Series No. 33. Auburn University, Alabama, pp. 25-47.

Hatch, U. and C.R. Engle, 1987. Economic analysis of aquaculture as a component of integrated agro-aquaculture systems: some evidence from Panama. Journal of Aquaculture in the Tropics, 2:93-105.

Hishamunda, N. and J.F. Moehl, 1989. Rwanda National Fish Culture Project. Alabama Agricultural Experiment Station: Research and Development Series No. 34. Auburn University, Alabama, 19 pp.

Hishamunda, N., M. Thomas, D. Brown, C. Engle, and C. Jolly, 1998. Small-scale fish farming in Rwanda: Data report. Pond Dynamics/Aquaculture CRSP, Office of International Research and Development, Oregon State University, Corvallis, Oregon, 26 pp.

Latham, M., 1965. Human Nutrition in Tropical Africa. Food and Agriculture Organization of the United Nations, Rome, 268 pp.

MINAGRI (Ministère de l'Agriculture, de l'Elevage et des Forets), 1987. Semaine Nationale sur la Vulgarisation Agricole. Document de Travail. Kigali, Republique Rwandaise, 192 pp.

Ministère du Plan, 1983. Stratégie Alimentaire du Rwanda: Objectifs et Programmes d'Action. Kigali, Republique Rwandaise, 90 pp.

Moehl, J.F., 1993. Aquaculture development in Rwanda: a case study of resources, institutions, and technology. Ph.D. dissertation. Auburn University, Alabama, 321 pp.

Molnar, J.J., A. Rubagumya, and V. Adjavon, 1991. Sustainability of aquaculture as a farm enterprise in Rwanda. Journal of Applied Aquaculture, 1(2):37-62.

Mpawenimana, P., 1991. Rapport Annuel du Service Pisciculture National. Miméo. Butare, Republique Rwandaise, 27 pp.

Rappaport, U. and S. Sarig, 1978. The result of manuring on intensive growth fish farming at the Ginosar station ponds in 1977. Bamidgeh, 30(2):27-36.

SAS Institute, Inc., 1985. SAS User's Guide: Statistics, Version 5 Edition, Cary, NC: SAS Institute Inc., 956 pp.

Service Météorologique, 1979. Stations Météorologiques du Rwanda. Miméo. Kigali, Republique Rwandaise, 16 pp.

Sikkens, R.B. and T.S. Steenhuis, 1988. Development and management of the small marais: In Water Management Synthesis Project Report 79. United States Agency for International Development, Kigali, Rwanda, 105 pp.

Sin, A.W. and K.W.J. Cheng, 1976. Management Systems of Inland Fish Culture in Hong Kong. Indo-Pacific Fisheries Council, IPFC/76/Symp., 519 pp.

Smith, L.J. and S. Peterson, 1982. Aquaculture Development in Less Developed Countries. Westview Press, Boulder, Colorado, 152 pp.

Weisberg, H.F., J. Krosnick, and B.D. Bowen, 1989. An Introduction to Survey Research and Data Analysis, Second Edition. Scott, Foresman and Co., Glenview, Illinois, 332 pp.

Wilcock, D. and V. Ndoreyaho, 1986. The Rwanda Social and Institutional Profile, Volume Two. Development Alternatives, Inc. Report. Washington, D.C., 152 pp.

Williams, J.C., 1993. Personal Communication. Auburn University, Auburn.

World Bank, 1989. Rwanda Agricultural Strategy Review. Report No. 4635-RW. The World Bank, New York, New York.

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