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AQUACULTURE DEVELOPMENT IN RWANDA - Feasibility of small-scale rural fish farming

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by U.W. Schmidt and M.M.J. Vincke

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1. INTRODUCTION

1.1 Context and Purpose of Report

1.1.1 Until recently Rwanda has been more or less self-sufficient as regards food supplies. Now, however, the estimated rate of population increase is greater than the rate of increase of food production. The traditional way of producing more food, by taking more land under cultivation, is no longer an adequate solution, partly because most of the remaining land is less fertile; average yields per hectare are already decreasing. Some of the fertile land is nowadays devoted to the cash crops which are necessary if various desirable goods not produced in the country are to be procured. If this is to continue, and if sufficient food is to be produced for a population that is expected to double in the next ten to fifteen years, more productive use must be made of the land and waters. At the same time, it is desirable to increase the amount of food available to the average individual and the proportion of animal protein in his diet.

1.1.2 To these ends, the Government of Rwanda is taking various steps to stimulate domestic food production, including activities aimed at increased catches from the capture fisheries in the lakes. They have also taken the initial steps toward embarking on a programme to increase the production of fish from the numerous subsistence-level ponds operated by farming families and groups of small farmers throughout the cultivated valleys, the productivity of which could be much improved. It is believed that there is scope for extending the area of land devoted to fish farming without incurring unacceptable reductions in the total amounts of other crops produced. Any fish surplus to local requirements would provide much-needed extra cash income. The proposal to stimulate development of fish culture at the family and cooperative level has been the subject of a request for financial aid from the Government of Rwanda to the International Development Agency of the United States of America (USAID).

1.2 The Mission

1.2.1 The representatives of USAID in Rwanda requested the assistance of FAO in assessing the potential for aquaculture development and in drawing up detailed proposals. Mr. U.W. Schmidt, the socio-economist on the staff of the FAO/UNDP Inter-regional Aquaculture Development and Coordination Programme (ADCP) visited Rwanda in June 1980 and again in September 1980 in the company of Mr. M.M.J. Vincke, the senior aquaculturist of the ADCP; this report is the result.

1.2.2 Other organizations are to provide reports to USAID on various other aspects of the proposed programme, including the possible long-term effects on the environment and ecology, and on public health. The introduction of improved systems of rural fish farming does not usually have serious adverse effects on environment or health and could, as indicated later below, be beneficial to the latter in some respects.

1.3 Scope of Report

The present report discusses the technical, economic, social and financial feasibility of small-scale rural fish farming enterprises in Rwanda and the factors inhibiting higher productivity and expansion; it also indicates the nature and amount of inputs required to carry out an effective programme of development aimed at a significant increase in supplies at acceptable costs.

1.4 Acknowledgements

Valuable information was provided by Dr. G. Mahy and Mr. P.B. Ndengejeho of the National University of Rwanda in Butare and by Mr. M. Monnon, who was at the time a member of a mission to Rwanda sponsored jointly by the United Nations Development Programme and the African Development Bank. The authors are grateful to many other private persons and officials of the Government and of USAID, and especially to Mr. E. Chiavaroli and Mr. J. Barker, of the latter agency, for their unfailing cooperation and assistance.

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2. FINDINGS AND RECOMMENDATIONS

2.1 Summary of Findings

2.1.1 During the last two decades, yields of edible fish from rural ponds in Rwanda have been so disappointing that farmers are reluctant to invest labour and time in this form of cultivation. Many ponds have been abandoned or not harvested regularly for a very long time. Nevertheless, there is keen interest among the rural population in the possibility of producing more food by fish farming.

2.1.2 The present state of affairs is due at least in part to the almost complete lack of support by way of technical advice and assistance, supply of inputs such as fingerlings, and general encouragement. It will require much effort of these kinds on the part of the Government to restore the former productivity of the existing ponds, to introduce better techniques and to expand production.

2.1.3 The Mission found no major technical or biological constraints to development of fish farming in rural Rwanda. The climate and the availability of sufficient land and water provide the essential basis for fish culture. The soils, while not inherently fertile, can be made productive. Raw materials (agricultural wastes, agro-industrial by-products) are available which might be utilized for supplementary feeding of fish or for fertilizing ponds, although the feasibility of using these will have to be evaluated in every case.

2.1.4 To re-establish fish culture in the rural milieu will however require substantial effort to strengthen the development infrastructure as regards technical development, training and extension work.

2.1.5 With respect to the national economy, fish farming can be expected to produce significant and positive benefits: it will provide much-needed protein for human consumption; give the small-scale farmer the opportunity to increase his cash income and diversify his products; it would make better use of some types of land than other kinds of farming; it would strengthen and diversify the internal market; it may also create some new employment opportunities.

2.1.6 A development project is proposed which is intended to provide rural families with technical assistance and advice in operating some 2 400 individual ponds of up to 500 m^2 each; this is expected to restore production to the former figure of about 180 t/year of fish, with a value of, say, Rw.F. 13.5 million. This estimate assumes, moreover, rather low yields and does not include the results of any expansion of fish farming by direct emulation of the activities undertaken as part of the project, once they are seen by non-participants to be successful. By the end of the project production could be expanding by 10 percent per annum.

2.1.7 Estimates and comparisons of costs and earnings suggest that fish is likely to be more profitable to the farmer than most other agricultural products. A 500 m^2 family pond is expected, when properly managed, to yield a gross return of Rw.F. 5 625 per year, with a considerable potential for increase. A rural family, using in the main locally available resources, can thus derive a minimum cash income of Rw.F. 2 250 per year from a 500 m^2 pond, while still consuming 45 kg of fish per year (a many-fold increase over the recent average per caput consumption); the only major input apart from family labour and agricultural wastes would be the fingerlings needed for initial stocking of the pond. Development on these lines would not cause changes in the existing social structure or patterns of production and behaviour, and can be integrated into the traditional rural life. Fish culture is technologically within the reach of the farming population; it can be expected to be assimilated by these traditional cultivators at least as readily as any other form of animal husbandry, because it resembles plant crop production more closely in many respects. As already mentioned, there is considerable interest among rural people in taking up fish farming.

2.1.8 The provision of the necessary development infrastructure and support to upgrade and expand fish culture in Rwanda and introduce improved techniques thus appears justified and desirable.

2.2 Recommendations

2.2.1 On the basis of the above findings, the following is recommended:

i. A development support structure should be established to facilitate the reactivation and expansion of fish culture, as a family venture or a group undertaking, in the rural areas of Rwanda. The major elements of such support should be: training of national staff, extension work and fingerling production.

ii. The development support should be organized through one national centre (for training, research, initial fingerling production, etc.), and a number of prefectural centres (as bases for extension work and fingerling production and distribution). Training facilities at the national centre should be extended and the fish ponds and other culture facilities at all centres should be modified in detail. See (v) below.

iii. Technical development should be undertaken to the extent necessary in order to adapt established fish culture practices to local conditions. Special emphasis should be on the rational use of locally-available materials such as feeds and fertilizers, in order to reach a high degree of self-reliance in fish farming.

iv. The performance of rural fish culture on the farm level should be monitored in order to establish feed-back mechanisms between fish farmers and the development support structure, and to facilitate periodic evaluation of the overall impact of the development effort.

v. To these ends international technical assistance should be obtained through the medium of a four-year development project. At least nine agronomists should be recruited and trained to take charge of the fish breeding centres and the training programmes. During the four years of the project, a total of 60 extension workers (moniteurs piscicoles) should be recruited and trained.

vi. Motivational support should be provided to farmers to induce them to take up or intensify fish culture; the consumption of fish should be encouraged; fish farming should be included in the curricula of schools, youth training centres, etc.

vii. The development support activities and the direct assistance to farmers should be so devised and conducted as to be consistent with the objective of making fish farming an integral element of rural production; the aspirations of the rural people should be taken into account, as well as the means available to them for successful development and innovation.

2.2.2 Details of the proposed programme of development can be found in Chapter 6 below and in the associated annexes and tables. A farm-level financial analysis is provided in Chapter 7; Chapter 8 considers macro-economic implications of the proposed programme; Chapter 9 discusses socio-economic considerations.

2.2.3 The above programme and recommendations refer to small-scale pond culture by individual farmers and cooperatives. A beginning would be made with simple culture of a single species, followed by the more efficient and productive polyculture as and when appropriate systems have been validated by experimental trials; pond fertilization and supplementary feeding would be introduced in the same way. Combined culture of fish with pigs, ducks and chickens might also be introduced.

Culture of fish in rice paddies and culture in cages would be the subjects of medium-term experiment but the usefulness or otherwise of such systems in Rwandan conditions would not have become apparent before the end of the four-year project.

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3. BACKGROUND INFORMATION

3.1 Geography and Climate

3.1.1 Rwanda is a mountainous, land-locked country on the watershed between the headwaters of the Zaire and the Nile, with an area of 26 338 km^2. It includes part of a major freshwater lake, Lake Kivu, numerous smaller bodies of fresh water and many rivers. The underlying rocks are volcanic but in many areas the gentler slopes are overlain by blanket bog (marais).

3.1.2 Two major climatic zones can be distinguished (Morris, 1979):

i. the zone between 1 300 m and 1 900 m in altitude (mostly over 1 500 m) which has two rainy seasons and an average annual rainfall of 1 000 mm to 1 100 mm. The average annual temperature is 20℃;

ii. the zone located along the Zaire-Nile watershed and the volcanic slopes, above 1 900 m and reaching over 2 500 m. Isothermal conditions prevail, according to altitude; the average mean annual temperature is 16℃. The lower part of this zone has a 2–3 month dry season; annual rainfall is 1 200 mm – 1 400 mm. The higher areas have no dry season and rainfall is greater.

In the eastern and south-eastern fringes of the country, at altitudes below 1 000 m, rainfall is less than 800 mm in places.

3.1.3 Extreme and average air temperatures in some localities are given in Table 1, which is taken from the Bulletin Climatologique du Rwanda, Année 1977. There is little recorded information on the temperature of the waters in the major rivers and lakes.

Table 1

Extreme Air Temperature and Average Annual Air Temperature (℃)

Locality	Tx	Tn	TM	TA	Ta
Kigali-Aéro	26.3	15.5	20.8	30.7	10.8
Kigembe	26.3	15.5	20.8	30.7	10.8
Butare-Aéro	25.1	14.0	19.7	29.7	11.4
Gikongoro	23.0	13.8	18.4	26.3	11.2
Ruhengeri-Aéro	23.7	11.1	17.5	27.1	7.5

Tx = average maximum temperature
Tn = average minimum temperature
TM = average temperature
TA = absolute maximum
Ta = absolute minimum

3.2 Population

3.2.1 Total population in 1978 was estimated at 4.8 million. It is believed to be growing at about 4 percent per annum, and is expected to double by the end of the century. The largest city is Kigali, the capital, with a population of 120 000; the next largest is Butare, the university town, with a population of 20 000. Ninety-five percent of the population live in the countryside. There are few villages, most people living in individual family settlements. The density of population varies from about 80 persons per square kilometre to 500; the average density is over 180/km^2, making Rwanda the most densely populated country in Africa.

3.2.2 The major ethnic group, the Bahutu, constitute nearly 90 percent of the population; they are traditionally cultivators rather than herdsmen.

In 1970, only 5 percent of the population were engaged in wage labour, the remainder being independent farmers.

3.2.3 The absolute poverty level is put at U.S.$ 65/year for the rural population and U.S.$ 120/year for urban dwellers. It is estimated (IBRD, 1977) that the incomes of 30 percent of the rural population and 60 percent of the urban are below this level.

3.2.4 Administratively, Rwanda is organized into ten prefectures, which are sub-divided in turn into 143 communes; these into 1 600 sectors; the sectors each into ten collines. The prefects, and the burgomasters in charge of the communes, are appointed officials. The administrative heads of the sectors and collines are elected.

3.3 Land Tenure and Use

3.3.1 Delepierre and Préfol (1972) estimate that of the total land resources of 2.6 million hectares, 1.25 million were suitable for farming, and only 102 000 ha of these were not already under cultivation in 1974 (IBRD, 1976); this land was however being taken into cultivation at a rate of 3.5 percent/annum. The same IBRD report put the total area of marshland (bogs, marais) at 84 000 ha, although Morris (1979) states a figure of 48 000 ha; of this, perhaps 20 000 to 30 000 ha might be usable for fish culture (Monnon, pers.comm., 1980).

3.3.2 Morris (1979) distinguishes four agricultural zones:

1. the lowlands in the east and southeast
2. the central plateau where more than half the population live
3. the highlands
4. the western plateau

Details of soil types, rainfall, crops and population quoted by Morris after Delepierre, are given in Annex 1.

3.3.3 In 1975, a total of about 830 000 farms with a statistical mean holding of about 1 ha (0.91 ha in 1979) existed in Rwanda. The average, by prefecture, is shown in Table 2.

Table 2

Areas of Family Farms by Prefecture

Prefecture	Family Farm (ares)	15% marginal error	
Butare	78.4	66.6	90.2
Byumba	83.8	71.2	96.4
Cyangugu	101.8	86.5	117.1
Gikongoro	99.3	84.4	114.2
Gisenyi	79.5	67.6	91.4
Gitarama	98.7	83.9	113.5
Kibungo	210.3	178.8	241.8
Kibuye	102.0	86.7	117.3

Kigali	135.0	114.8	155.3
Ruhengeri	115.0	97.8	132.3
Rwanda	103.6	88.1	119.1

Source: IBRD, 1977

In the Byumba Prefecture the size distribution in 1973 was as follows (IBRD, 1977):

i. 36% of the farms have less than 80 ares (half the average);

ii. 35% of the farms have between 80 and 160 ares (between half the average and the average);

iii. 29% of the farms have more than 160 ares (the average) and the largest are five times the size of the average.

The study also showed a fragmentation of the farm into an average of five fields, some of which were 15 to 30 minutes walking distance from the homestead.

3.3.4 Agricultural production has traditionally been and still is based on the nucleus family. The nucleus family comprises the farmer, his wife (or wives, because of the once widespread, but lately diminishing, practice of polygamy), and their unmarried children. It may also include unmarried brothers or sisters and the old. The nucleus family produces for subsistence and the market, forming an almost self-sufficient and independent production unit. Inheritance is patrilinear, i.e., the father will pass on house, land, tools, etc. to his sons. If he has more sons than the existing land will support, he has to claim new land for them by bringing it under cultivation. The role of larger kinship groups, which formerly had a strong influence in land allocation, has been increasingly taken over by the administration (commune), which now have to approve any land transfer.

Farmers have a traditional, rather than a legally defined right to land. Legally all land belongs to the Government and transfers of land-use rights or allocation of newly cultivated land have to be approved by the burgomaster of the respective commune. In some areas a trend to buy land-use rights has been reported in recent years. Financially better-off farmers, usually the ones who grow mainly cash crops, thus gain control of seven or more hectares and employ the former cultivators on a full-time wage labour basis.

3.3.5 The greater part of the farm produce is consumed by the farmers themselves; it is estimated that only 41.9 percent of the total rural production is marketed. The following table gives an overview of the scale of marketing according to the sectors of the economy:

Table 3

Proportion of Goods and Services Entering the Market

Sector	Percentage marketed
Food crop production	30.8
Industrial and export crops	100.0
Livestock	35.1
Forest products	59.5
Fish	19.4
Total rural production	41.9
Mines and industries	87.2
Tertiary activities	100.0
Gross National Product (GNP)	69.5

Source: Ministère du Plan, Année 1976, Projections, In: IBRD, 1977

3.3.6 The cash crops - coffee, tea, pyrethrum, cinchona bark and so on - account for three-quarters of all earnings of foreign exchange. The Government exercises direct influence on farmers to increase cash crop production. In the Government organized settlement schemes, farmers are obliged to produce a certain quota of cash crops, otherwise their land-use right is threatened.

3.4 Food Supplies

3.4.1 Traditionally, Rwanda has been self-sufficient as regards food. Now, however, population growth is outstripping food production; at the same time there is a continuing and growing need to earn foreign exchange by cultivation of cash crops. As already noted, uncultivated but fertile land is becoming scarce.

3.4.2 The average diet amounts to only about 2 000 calories per caput a day and is apparently deficient in animal protein. (The normal sources of animal protein in Rwanda are cattle, goats, sheep, pigs and poultry, dairy products, fish and a little game. Morris (1979) quotes the following figures for consumption of foods rich in animal protein: meat from 0.5 kg/year to 18.9 kg/year/head; fish, zero to 5.6 kg/year; milk, 0.8 1/year to 17.8 1/year. The official figures for fish production suggest an average consumption of 0.175 kg/year; this estimate may be low since about four-fifths of what is produced is consumed without entering any channel of trade (Table 3). Nevertheless, given that to get 30 g of animal protein per day it is necessary to consume between 140 g and 220 g of fresh meat or fish a day, i.e., 50 to 80 kg/year, it is fairly certain that the average diet in Rwanda provides too little animal protein.)

3.4.3 The Government is taking active steps to intensify and diversify both food production and export crop production, in order to meet the nutritional demands of the increasing population to raise rural incomes and to generate rural employment.

3.4.4 It would be difficult to expand meat production, both for reasons of tradition and because good pasture land is scarce. Good arable land, as already noted, is also becoming scarce, but there are possibilities of cultivating the 'marais' (marshlands). Formerly, the then feudal elite, the Tutsi, reserved bottom land for cattle grazing. Studies of how the 'marais' could be better utilized have been under way for a number of years.

The fringes of many marshes are already being used by farmers as a valuable complement to their rain-fed farm land on the hill slopes. In this way, the farming system has a better use of labour in the dry seasons at a very low investment cost (Morris, 1979).

An additional way of utilizing the 'marais' for food production would be cultivation of fish in ponds, and this is the main opportunity for increased fish production.

3.4.5 Taking all these factors into consideration, the Government have accorded high priority to the expansion of fish production both by capture fisheries and by aquaculture.

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4. THE FISHERIES

4.1 Supply, Demand and Price of Fish

4.1.1 The Ministry of Agriculture and Livestock, in their 1978 Annual Report[1], estimated the output of lake fisheries during that year at 709 256 kg. The existing 2 662 fish ponds (see Table 5) produced an additional 15 277 kg during that year according to official figures which are not complete; the Mission estimated a total of 18 891 kg.

4.1.2 These figures suggest an extremely low consumption: below 3 g per caput and per day (Aubray, 1976), the overall consumption of protein foods being 46.8 g per caput and per day in 1978, according to the 1978 annual report of the Ministère de l'Agriculture et de l'Elévage.

4.1.3 This significant lack of animal protein indicates a substantial potential demand for fish in Rwanda, in spite of the fact that fish is not part of the traditional local diet in the country. Reizer (1975) observed a daily per caput fish consumption of 50 g in a Government settlement scheme (paysannat) close to Lake Kirimbi and used this figure as the basis for estimating the potential fish consumption in Rwanda. He estimated the potential demand at four levels, at 63 g/day (his estimate of the optimal intake level to compensate for the overall protein deficiency) at 50 g/day, at 100 g/week (to allow two meals of fish), and at 50 g/week (to allow one meal with fish). His demand projections are summarized in Annex 2. They range from 13 000 t/year to 113 000 t/year. Either figure is greatly in excess of present production.

Again, considering the urban population, and assuming a consumption level of 5 kg/year per caput (compare the national average of 4 kg to 5 kg for Burundi; 15 kg for Uganda and 13 kg for Tanzania) this very small section of the population alone might create an annual demand of over 1 000 tons, more than the present total supplies.

4.1.4 Fish is consumed fresh, dried and smoked. Fresh fish commands the highest prices. The World Bank records a controlled price for fresh fish of Rw.F. 55/kg in 1975 (IBRD, 1977). At present, prices to the consumer fluctuate between Rw.F. 60 and 140/kg.

[1] Ministère de l'Agriculture et de l'Elévage. Rapport Annuel 1978, Kigali, République Rwandaise, 1979

4.2 Potential for Expansion

4.2.1 Part of the potential (future) demand for fish could be satisfied by the expansion and intensification of the capture fisheries. The Government are taking active steps in these directions. The potential according to Mahy (1979) is over 16 000 t/year; if this is a theoretical maximum based on biomass estimates and reproductive cycles it will not have taken into account practical limitations, such as, for example, that a successful commercial fishery cannot develop except when the behaviour of the fish facilitates the use of one or other of the known methods of capture, and that not all of the catch may be regarded as edible or marketable. Even if it is a realistic figure, based on analysis of catches and effort, it should be regarded as a figure to be approached but not attained, since it is seldom good economics to attempt to take the maximum sustainable yield. Thus, at best, it is likely that only the lowest of Reizer's estimates of potential demand could be met by concentrating all development on the capture fisheries. Both Reizer (1975) and Aubray (1976) thought the possibilities for their development rather limited. Sustained yields would also depend on effective control of effort and management of the fisheries, which in Lake Kivu would require effective international cooperation.

4.2.2 The expansion of aquaculture is the other possible way of increasing fish supplies. There is already some tradition of fish farming, considerable interest in its possibilities on the part of farmers, and apparent opportunities to rehabilitate existing ponds and create new ones. Among the more obvious advantages is that much of the fish could be produced where it is to be consumed, whereas a large proportion of the production of the capture fisheries would have to be transported over some distance before it could be marketed.

4.3 Present State of Aquaculture

4.3.1 Fish farming began in Rwanda at the end of the forties and was actively fostered by the Belgian colonial administration. At the end of the fifties the total pond area under production was about 450 ha (Aubray, 1976), producing some 180 t/year: an average yield of about 400 kg/ha/year.

Two main fingerling production centres were constructed during this period: at l'Ecole des Assistants Agricoles, Butare, in 1952: and the Kigembe Station in 1954.

During the years 1960–65 development of fish culture in Rwanda came to a standstill and many existing ponds were abandoned. The main reason for this was the disappearance of the support for rural fish farming by way of extension services, fingerling production, training, technical advice, and so on, formerly provided by the colonial administration. Nevertheless, it was estimated that 448 ponds still existed in 1966, with a total surface of 84 ha approximately (Meschkat, 1967).

The Government resumed an active interest in small-scale fish farming in the late sixties. During the years 1967–73 two UNDP/FAO projects were implemented with the aim of reactivating the Kigembe Centre and of carrying out trials on culture of common carp, Tilapia macrochir, T. rendalli and Clarias carsonii. Tilapia fingerlings were produced and several ponds in rural areas were stocked again.

On 5 April 1970 an agreement between the Ministère de l'Agriculture et de l'Elévage and CRDI (Centre de Recherches pour le Développement International, Ottawa, Canada) was signed to implement the ELADEP Project ('Empoisonnement des lacs du Pays et Développement de la Pêche'). The headquarters of this project are at the Ruganwa Fish Station at Kigali. ELADEP's main activities are experiments in growing different species in aquaria and ponds at the Ruganwa Fish Station and the Kigembe Centre and the training of extension workers (moniteurs piscicoles) at Kigembe. ELADEP has activities also at the Rusumo Fish Station (Karangwa, 1979). All the people from Rwanda who have so far been trained in fish farming and fisheries at the 'Centre de Formation' in Bouaké, Ivory Coast, have been assigned to this project.

4.3.2 By 1978, the number of ponds, surface area and the production were as given in Table 4. According to these figures, the average yield is now less than 200 kg fish/ha/year. The average surface of the ponds is 2.92 ares.

Table 4

Census of Fish Ponds
(1978)

Prefectures	No. of ponds	Total surface (ha)	Average pond area (ares)	Production (kg)	Average yield (kg/ha/year)
Kigali	653	12.91	1.97	1 500	116.2
Gitarama	626	12.57	2.00	690	54.9
Butare	541	23.16	4.28	969	41.8
Gikongoro	160	4.54	2.83	1 105[1]	243.3

Cyangugu	32	0.94	2.93	229[1]	243.3
Kibuye	151	2.03	1.34	604	297.5
Gisenyi	183	9.96	5.44	42	4.2
Ruhengeri	93	2.16	2.32	2 745	1 270.8
Byumba	183	8.31	4.54	2 022[1]	243.3
Kibungo	40	1.06	2.65	258[1]	243.3

[1] Production figures not quoted, but calculated by the Mission on the average yield obtained in the ponds in the other prefectures (243.3 kg fish/ha/year). The annual estimated production is thus 18 891 kg instead of 15 277 kg

Source: Ministère de l'Agriculture et de l'Elévage - Rapport Annuel 1978

4.3.3 At present only two species are commonly cultured: Tilapia melanopleura (it may be T. rendalli and not the true T. melanopleura) and T. macrochir. Tilapia nilotica is also raised, but only in Kigali. Clarias carsonii, C. mossambica, Serranochromis macrocephela and Cyprinus carpio (common carp) are also to be found in a few ponds.

Fingerlings of grass carp (Ctenopharyngodon idella) and according to reports other Chinese carps, including silver carp (Hypophthalmichthys molitrix) were introduced in December 1979 at the Ruganwa Fish Station in Kigali by a North Korean Mission. The object is to rear the carp to maturity and try to spawn them for fingerling production. Trials on induced spawning will start in December 1980. The average weight of the grass carps was around 2 kg in September 1980.

4.3.4 The Annual Report (1978) of the Ministry of Agriculture and Livestock records the construction of seven prefectural fish breeding stations:

Gitarama:	Rugeramigozi Swamp near Kabgayi (Gitarama commune)
Gikongoro:	Nkungu
Cyangugu:	Ntendezi (Kagano commune)
Kibuye:	Rehabilitation of the Fisheries Station at Nyamishaba
Gisenyi:	Kazabe
Kibungo:	Rusumo
Ruhengeri:	Rehabilitation of the Fisheries Station at Muko

4.3.5 The state of aquaculture in the seven prefectures where fish production is considered to be of high priority is summarized in Table 5.

Table 5

State of Aquaculture in the Seven Prefectures
where Development of Aquaculture is considered as a Priority

Prefecture	Inhabitants (1974)	Density of population (inhabitants/km^2)	Situation of existing ponds (1978)					Inhabitants involved in fish farming (%)
			Number	Total area (ares)	Total production (kg)	Average production (kg/are/year)	Average area of ponds (are)	
Kigali	445 425	137	653	1 291	1 500	1.162	1.97	0.14
Gitarama	532 599	237.7	626	1 257	690	0.549	2.00	0.12
Butare	606 589	331.5	541	2 316	9 696	4.180	4.28	0.09
Gikongoro	367 886	167.8	160	454	1 105	2.433	2.83	0.044
Ruhengeri	517 171	293.5	93	216	2 745	12.700	2.32	0.010
Byumba	411 858	82.6	183	831	2 022	2.433	4.54	0.04

Kibungo	279 641	67.6	40	106	258	2.433	2.65	0.015
Total	3 161 169	-	2 296	6 471	18 016	-	-	-

4.3.6 In 1979 the Ministère de l'Agriculture et de l'Elévage prepared a programme for aquaculture development to be carried out in each of the prefectures and communes of the country.

The programme provides for (Minagri, 1979) the building of a fish breeding station composed of 16 ponds each of 15 ares in each of the ten prefectures; and the building of one communal fish breeding station of 12 ponds of 10 ares each in each of 100 communes.

The total area of these stations will be:

			ares	ha
Prefectures	10 stations × 240 ares		2 400	24
Communes	100 stations × 120 ares		12 000	120
		Total	14 400	144

No detailed cost estimates were available but the Government estimates the cost of construction (including excavation works, construction materials, etc.) to be Rw.F. 2 000 000 (U.S.$ 21 978) per hectare. Total cost for 144 ha would be Rw.F. 288 million (U.S.$ 3 169 230).

4.4 Research, Development, Training

4.4.1 There are four institutions in Rwanda which could carry out training and research in fish culture:

- 'Institut des Sciences Agronomique' at Rubono/Kigali
- 'Institut National de la Recherche Scientifique' at Butare
- 'Université National de la Recherche Scientifique' at Butare
- 'Institut National de Pedagogie' at Butare

At present, however, training and research efforts by these institutions are insignificant, the National University at Butare being the only one which offers specialized courses in Fisheries Biology and Fish Culture; in 1980 only four students received a degree in this discipline.

Rwandans with appropriate entrance qualifications could attend external training and research centres such as the FAO/UNDP Regional Aquaculture Centre in Nigeria and the Fisheries School in the Ivory Coast. These people, however, can never constitute more than a very small cadre of highly trained specialists.

4.4.2 Agriculture and fisheries extension work is organized by prefectures and communes, with prefectural and communal extension workers (agronomists, A2), sectoral extension workers (agronomists, A3) and extension workers who act on the colline level (moniteurs).[1]

Extension personnel officially working for fisheries and fish culture comprised, in 1978, four specialized A2 agronomists (working mainly in lake fisheries), two other A2 agronomists, four A3 agronomists and 23 extension staff without special training. A prefectural breakdown is given in Table 6.

[1] A2 agronomists are usually graduates of the Agricultural University and A3 agronomists of agricultural colleges. Moniteurs have little or no educational background above that of basic schooling.

Table 6

Fisheries Extension Personnel
(1978)

Prefectures	Agronomist A2	Agronomist A3	Assistant Agronomist	Extension Agent	Extension Workers (Moniteurs)	Extension Workers (Agents)	Fishery Warden
Kigali	1	-	-	-	-	4	4
Gitarama	-	-	-	1	-	-	-
Butare	-	1	-	-	2	-	-
Gikongoro	-	-	-	-	-	-	1
Cyargugu	-	-	1	-	-	-	1
Kibuye	-	1	1	-	-	-	-
Gisenyi	1	-	1	-	-	-	1
Ruhengeri	1	-	-	-	-	-	2
Byumba	-	-	-	-	-	-	1
Kibungo	1	-	1	-	-	1	5
Total	4	2	4	1	2	5	15

Source: Ministère de l'Agriculture et de l'Elévage - Rapport Annuel 1978

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5. TECHNICAL CONSIDERATIONS

5.1 Soil, Climate and Ecology

5.1.1 The areas of Rwanda best suited for cultivation of fish are the flat valley bottoms with very gentle slopes, which lend themselves to easy construction of ponds. Most existing ponds are in such areas.

5.1.2 Water supply would not be a constraint. Records of air temperatures suggest that in some places the temperature of the water may drop below 10°to 12℃ for a sufficiently long time to cause mortalities of fish of such species as Tilapia rendalli, T. mossambica and T. nilotica, although the Mission is not aware of any actual incidents of this kind. When water temperatures are below 17°to 18℃ in June, July and August, til apia will not spawn and growth rates will be poor. It will, therefore, have to be accepted that fingerlings will not be available for three months in the year and the main growing season will be from September to the end of May.

5.1.3 The peat soils are cold, acid, deficient in calcium and in other minerals, including phosphorus, and in available nitrogen. Biological productivity is therefore comparatively low, and corrective measures are necessary to achieve good results when cultivating fish or other crops. These measures include use of lime and fertilizers and are discussed in more detail later below.

In some cases drying out adversely affects the mechanical and physico-chemical properties of the peat: it becomes irreversibly compressed and hydrophobic; it would be necessary to maintain the water table as high as possible to avoid these problems.

In some cases the content of sulphur compounds is high enough to make the soil acid and unsuitable for nearly all sorts of cultivation, but if fish ponds were constructed in such soils, the condition could be corrected by repeated flushing of the ponds to leach out the sulphates.

The very fibrous peaty soils formed from reeds or Cyperacae are not suitable for fish farming.

An account of the various types of peaty soil encountered in Rwanda, the methods used to reclaim them for cultivation and the appropriate treatments to enhance or retain fertility can be found in Annex 3. Before constructing fish ponds, a detailed survey including soil analysis is advisable.

5.1.4 Both malaria and schistosomiasis occur in Rwanda. The marshalands provide habitats suitable for mosquito larvae and bilharzia snails and so do fish cultivation ponds, but in the latter case it is possible by various means to control the concentrations of these animals at a low level so that the risk of contracting disease is low. See 5.3 below.

5.1.5 The natural productivity of waters in Rwanda is between 100 kg/year and 300 kg/year/ha. To achieve a better production it is necessary to feed the farmed fish, or to fertilize the ponds, or both; species of fish that respond to this treatment by growing fast and converting the available food efficiently have to be chosen. This in turn means, in practice, that farmers would have to be supplied with fingerlings of these species, at least for initial stocking. These matters are discussed in detail later below. First, the systems of fish culture that appear worthy of consideration for small-scale rural enterprises in Rwanda will be briefly described.

5.2 Systems of Aquaculture

5.2.1 Systems of fish cultivation appropriate to Rwandan conditions would include monoculture of Tilapia nilotica; polyculture with T. nilotica as the main species (the secondary species including other tilapias, Clarias spp. as predators, and snail-eating species such as Haplochromis mellandi and Astatoreochromis alluaudi); culture of fish in association with husbandry of animals such as pigs, ducks or chickens; perhaps rice-cum-fish culture; and perhaps also cage culture with fully artificial feeding. The considerations governing choice are set forth below.

5.2.2 Monoculture

At the initial stage of rehabilitation of the existing ponds, and as farmers are not yet trained and not well accustomed to fish farming, it is foreseen that they would first raise T. nilotica in monoculture, going progressively over to polyculture and/or integration of fish farming and animal husbandry (pig-cum-fish culture).

5.2.3 Polyculture

Natural food in ponds (increased by fertilization) and supplemental feeds are not completely consumed if only one species is cultured in the pond and better yields are obtained with polyculture. Choice of species is discussed in 5.3 below. Suggested combinations and stocking rates are in Annex 4.

5.2.4 Integration of fish farming and animal husbandry

An effective and economical system of fish production involves the raising of pigs, ducks or chickens in pens beside or over fish ponds to provide a source of continuous organic fertilization. It works very well in polyculture of T. nilotica and common carp and also with other combinations. This practice increases the efficiency and profitability of both animal husbandry and fish culture by utilizing animal and feed wastes and can produce yields higher than any other system of fish farming.

Details of systems of this kind are given in Annex 5. None have yet been tried in Rwandan conditions, and they should be the subject of experimental trials in due course when resources permit.

5.2.5 Rice-cum-fish culture and cage culture of fish with full artificial feeding have likewise not been tried in Rwandan conditions and should be the subject of experimental trials as and when sufficient resources and experience become available.

5.3 Choice of Species

5.3.1 The main species cultured at present in Rwanda are Tilapia melanopleura (or T. rendalli) and T. macrochir. Tilapia nilotica and common carp are also raised in ponds, but on a very small scale. Tilapia macrochir and T. rendalli are not fast growing species and experience elsewhere in Africa suggests that incremental growth rates are generally only 0.5 g/day and never exceed 1 g/day, even with fertilization of the ponds and artificial feeding. Clarias carsonii occurs sometimes in ponds, but it is a relatively slow-growing species which never reaches more than 20 cm. These species should only be considered suitable for farming in polyculture with fast-growing species, such as T. nilotica, common carp (Cyprinus carpio), Clarias mossambica, C. lazera. Eventually, grass carp (Ctenopharyngodon idella) and silver carp (Hypophtalmichthys molitrix) can be raised if these Chinese carps can be acclimatized in Rwanda, and if adequate quantities of fingerlings can be produced.

5.3.2 As a predator on undesirable animal organisms C. mossambica can be used, but if natural spawning does not occur in ponds or if induced spawning is not successful, one could utilize instead C. lazera which has been cultured successfully in the Central African Republic and in the Ivory Coast.

5.3.3 Growth rate increments under good conditions (fertilization of the ponds and artificial feeding) can be expected from experience elsewhere in Africa to be between 1 and 2 g/day for T. nilotica; 2–4 g/day for C. lazera; 8–14 g/day for common carp; and 6–8 g/day for silver and grass carp.

5.3.4 As bilharzia (schistosomiasis) is a common disease in Rwanda all fish ponds, dams, rice fields and swamps should be stocked with a few of the malacophageous species Astatoreochromis alluaudi and Haplochromis mellandi (Vincke, 1972). Some other species, which are not snail eaters, but selective plankton eaters or feeding only on periphyton (biota growing on stems and leaves of submerged aquatic weeds) are also effective in reducing the number of snails because they destory the eggs which adhere to the stems of submerged plants, such as Potamogeton, Myriophyllum and Ceratophyllum, to the lower face of the floating leaves of Nymphea, Azolla, Pistia stratiotes or Salvinia natana, or to the roots and leaves of the water hyacinth (Eichornia crassipes). Species feeding on periphyton are T. nilotica, T. mossambica and T. zilii. Herbivores such as T. rendalli and grass carp also destroy eggs when they eat aquatic plants.

5.4 Fingerling Production

5.4.1 One of the main constraints to the expansion of fish production by aquaculture is the poor availability of fingerlings of the species most suitable for culture (5.3 above).

5.4.2 Tilapia nilotica fingerlings have been available only at the Ruganwa Fish Station near Kigali, but arrangements were in hand to transfer some to Kigembe in October 1980. A few fingerlings of T. rendalli and T. macrochir are available at Kigembe.

5.4.3 An outline of the techniques that would be required for successful and economical production of fingerlings can be found in Annex 6. The sizes of ponds in the planned breeding stations (4.3.6) seem too large. The requirements for fingerlings to support a planned programme of development are indicated in 6 below.

5.5 Supplementary Feeds

5.5.1 Supplementary feeding will enhance the growth rates of farmed fish and increase productivity per unit area of pond. Whether it is economic, however, depends upon the availability of suitable raw materials and their costs, including costs of transport and of any processing to which they have to be subjected to make them suitable as feed stuffs for fish.

5.5.2 The need to include animal protein in the supplementary feeds depends upon species and its inclusion is not considered essential when cultivating tilapias and Clarias.

5.5.3 Table 7 lists some agricultural and industrial waste products found in Rwanda that could possibly be used as raw materials for fish feeds. The table also indicates the quantities produced and where and at what time of year they are available. It is not clear, however, to what extent some or all of these by-products and wastes are already utilized as animal feeds, agricultural fertilizers, as domestic fuel or for other purposes. To the extent that they are already so used, their diversion to fish farming would bear an opportunity cost. However, to use them to produce animal protein should, in theory, be more efficient than using them as fertilizer or fuel.

Table 7

Availability of Agro-Industrial By-Products

Agro-industrial by-products	Localities	Availability (tons/year)	Period of availability	Cost (Rw.F.)
Draff (wet)	Gisenyi[a]	1 400	all year	free of charge
Beer yeast	Gisenyi[a]	200 000 litres	all year	free of charge
Draff from banana beer	all countries	87 000	all year	2/kg

Draff from sorghum beer	all countries	20 800	all year	2/kg
Blood meal	b	390	all year	free of charge
Stomach contents	b	800	all year	free of charge
Bone meal	b	c	all year	free of charge
Rice brans	Kigali	74	March, Sept.-Oct.	2 000/ton
Rice polishings	Kigali	149	March, Sept.-Oct.	2 000/ton
Wheat brans	Ruhengeri[d]	193	all year	2 000/ton
Remouldings (wheat)	Ruhengeri[d]	262	all year	2 000–2 500/ton
Bagasse	Kabuye	2 100	all year	free of charge
Molasses	Kabuye	350	all year	to be assessed
Filter press mud (cane)	Kabuye	c	all year	to be assessed
Maize bran	all countries	e	all year	2 000/ton
Groundnut cake	f	c	all year	to be assessed
Soya oil cake	Kigali	10 000	all year	to be assessed
Coffee pulp	all countries	100 000	all year	to be assessed
Coffee hulls	all countries	3 000	all year	to be assessed
Cassava offals	all countries	c	all year	to be assessed
Household scraps	all countries	c	all year	to be assessed
Other wastes	all countries	c	all year	to be assessed

Notes: [a] A new brewery will be established presently in Kigali.
[b] Available in the three abattoirs (Kigali, Butare and Rusumu),
[c] 28 slaughterhouses and 276 unimproved slaughter places.
[d] Figure not available. Quantities should be assessed.
[e] A new wheat mill will be installed soon at Adikongoro.
[f] Available in almost every village, but in small quantities.
[g] Available in Cyangugu, Kibuye, Gisenyi, Gitarama and Kigali prefectures.

Annex 7 discusses the treatment and utilization of these materials at some length. Annex 8 indicates how suitable diets might be formulated from raw materials available in Rwanda; the 25 percent protein diet should be used for fingerlings and adults; the 30 percent protein diet for fry.

The extent to which such diets can be or should be used in fish farming in Rwanda will be a matter for practical trial. One constraint may be local availability: if such materials have to be transported more than a certain distance (perhaps 50 km) their utilization in fish farming may be uneconomic.

5.6 Fertilizing the Ponds

5.6.1 Lime will have to be used to correct the acidity of peat soils and of the water in areas where they occur.

5.6.2 To obtain high yields with T. nilotica, T. macrochir and common carp (C. carpio), fertilization of the ponds has to be carried out regularly.

Either organic or inorganic fertilizers may be used, but recent increases in the price of chemical fertilizers may greatly limit their use in Rwanda, taking also into account local transport problems, especially in remote areas.

Inorganic fertilizers include superphosphates, ammonium compounds and urea. Organic fertilizers might include animal manures, vegetable compost and artificial manure; the last named is made by composting vegetable matter and adding urea or some other source of nitrogen.

Details of the use of various fertilizers and, in appropriate cases, their manufacture, are given in Annex 9.

5.7 Yields

5.7.1 In estimating the likely yield per hectare from small-scale rural ponds in Rwanda, experience has been taken into account from elsewhere in Africa and in other tropical regions where fish farming of the species under consideration is already established. Yields of 3 to 3.5 t/ha/year are attainable in rural small-scale aquaculture by skilled management cultivating the right species; an average yield when culturing T. nilotica might be 1.8 to 2.0 t/ha/year.

5.7.2 The assumption made later below (Chapter 6), namely an average yield of 1.5 t/ha/year, therefore seems conservative. However, it takes into account the fact that performance is found to vary from 0.7 to 0.8 t/ha/year or less with comparatively unskilled management of the ponds and no fertilization or feeding, to 5.5 t/ha/year and more for skilled management of large ponds with regular fertilization and daily feeding of fish.

5.7.3 It would take some years to acquire sufficient knowledge, experience and skill to attain such a high level of performance as 5.5 t/ha/year, and only a minority of farmers can be expected to do so - perhaps one in eight or one in ten. One-third to one-half of the farmers can be expected to achieve an average of 2.4 t/ha/year in due course; about the same number will probably never average more than 0.7 to 0.8 t/ha/year.

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6. PROPOSALS FOR ACTION

6.1 The Opportunity

6.1.1 Development and expansion of fish culture appears to be one of the most promising ways of bridging the gap between the present supplies of and the potential demand for animal protein foods. Systems of culture exist that would be appropriate to the soil and water conditions and to the way of life of the small-scale farmers, who are indeed already familiar with fish farming and express keen interest in its possibilities.

6.1.2 The farmers need help and support of various kinds to ensure success and make the effort of rehabilitating ponds and constructing new ones worthwhile, as is indicated below.

6.1.3 As will also be shown below, fish farming can provide a readily-available additional supply of animal protein foodstuffs to the farming family as well as a potential source of extra cash income, without affecting to an unacceptable extent other productive activities; indeed, the immediate benefits in food and income would be greater than for most other crops.

6.2 Objectives

6.2.1 The development programme should be undertaken with the following long-term objectives:

i. to help meet the nutritional demands of the increasing population;
ii. to help diversify and intensify food production by small-scale farmers;
iii. to raise rural incomes;
iv. to generate rural employment.

6.2.2 The short-term objectives should be:

i. to restore the level of production of fish by small-scale farmers to 180 t/year;
ii. to achieve a rate of increase of production thereafter of, e.g., 10 percent/annum;
iii. to improve the productivity of fish farming in rural ponds in terms of land usage and labour inputs;
iv. to create a permanent technical capability in Rwanda in the field of aquaculture so as to ensure that levels of production and productivity achieved in the course of the programme can be maintained, and that they can be increased or improved as may be seen to be necessary and desirable.

6.3 Outline and Justification of Proposed Programme

6.3.1 A four-year programme of development is proposed. In the early stages, existing ponds would be rehabilitated and a beginning made on constructing new ponds and bringing them into production; also the total area of pond cultivated by the average family participating in the programme would be enlarged. Progressively, the productivity of the ponds would be improved by introducing the use of fertilizers and by introducing the practice of supplementary feeding.

6.3.2 In order to implement such a programme and ensure a high probability of a successful outcome, it is necessary to provide encouragement, technical advice and demonstration and training; it is also necessary to produce and organize the distribution of fingerlings, fertilizers and supplementary feeds, and to provide technical support through a modest programme of directly relevant research and development. The Government would have to take the initiative and provide the impetus in the early stages; the provision of extension services and other supporting activities would have to be undertaken through the public service. The Government should seek international assistance in carrying out the programme through the mechanism of a development project.

6.3.3 The prefectures benefiting from the project activities would be the seven in which there is greatest apparent need to increase the supply of animal protein food stuffs: Kigali, Gitarama, Butare, Gikongoro, Ruhengeri, Byumba and Kubungo.

In 1978 there were 2 296 ponds in these seven prefectures, with a total area of 5 158 ares which produced 9.3 tons of fish at an average yield of 0.18 t/ha/year (Table 5). During the first year of the programme, four-fifths of these ponds should be rehabilitated, enlarged and restocked, and new ponds constructed, making 1 922 modernized ponds in all, with a total area of 6 750 ares. These ponds can be expected to produce over 30 tons of fish by the end of the first year, at an average yield of 0.5 t/ha/ year (Table 8). The area of the average pond would have been increased from 2.25 to 3.5 ares; the number of new ponds would be increasing by 3 to 5 percent/annum.

By the end of the fourth year (Table 9) the number of ponds would be 2 334, with a total area of 11 670 ares. Yields can be expected to increase to 1.5 t/ha/year, giving a total production of 175 tons of fish in the fourth year.

This takes no account of any additional production that may occur as a result of emulation or adoption by other farmers, not participating in the official programme, of the methods disseminated through the activities of the project.

6.3.4 By the end of the fourth year, the average family participating in the programme would be operating a pond or ponds with an area of 500 m^2 and producing 75 kg of fish a year. If the average selling price is assumed to be Rw.F. 75/kg (a modest assumption: see 4.1.4 above), then the total value of the annual production of the average family pond would be Rw.F. 5 625. However, some, perhaps most, of the fish produced would be consumed on the farm. If the average farmer and his family consumed 45 kg (equivalent to slightly less than 10 kg per caput/ year), then cash income from sale of the remainder would be Rw.F. 2 250 for the year. The inputs required would be fingerlings for initial stocking of the pond, family labour and agricultural wastes. It will be argued later below (Chapters 7 and 9) that the provision of these inputs will not be especially onerous or raise any special difficulties, while the returns would be higher in relation to the resources employed than for almost any other crop suitable for the same land.

6.3.5 The programme should, therefore, produce an additional 166 t/year of fish by the fourth year, representing an increase in the Gross Domestic Product (GDP) of over Rw.F. 12 million. This takes no account of the multiplier effect - the example of successful units inducing non-participants to start fish farms of their own.

6.3.6 As far as can be foreseen at present, fish production by aquaculture should be capable of expansion by about 10 percent/annum for some years after the end of the project without encountering constraints such as scarcity of land or other inputs, provided that the extension services and other forms of support recommended below are maintained and fully active.

6.4 Government Action

6.4.1 In order to carry the above programme to a successful conclusion and meet the proposed objectives, the Government would have to undertake a number of actions. These include recruiting, training, equipping and employing a much enlarged aquaculture extension service; reinforcing the national centre for aquaculture and the prefectural fish breeding stations and equipping them to provide supplies of fingerlings of the recommended species and to act as demonstration centres and sources of technical advice; and carrying out research and development in direct support of the programme. The Government must also, by persuasion and promotional activities, gain acceptance for the programme, induce individual farmers to participate and local communities to cooperate, and popularise the consumption of fish.

6.4.2 Extension service

(i) Nine agronomists at A-2 level would be required for the proposed programme: two at the Kigembe station (one as head of the station and programme leader; one as a senior instructor); each of the other seven would be responsible for managing one of the prefectural breeding stations, and for the technical supervision of the field extension workers (moniteurs) in his prefecture. These nine staff should receive training from international experts at the Kigembe station at the beginning of the project. Their training should be of a practical nature and should last for 5 or 6 months.

Table 8

Fish Culture Programme at the End of the First Year

Prefecture	No. of existing ponds (1978)	Rehabilitated ponds[a]		Rate of construction of new ponds[b] (%)	Ponds and production, v			No. of fingerlings needed for stocking[e]
		No.	Surface (ares)		No.	Area[c] (ares)	Production[d] (kg)	
Kigali	653	522	1 028	+ 5	548	1 644	8 220	328 800
Gitarama	626	500	1 005	+ 5	525	1 575	7 875	315 000
Butare	541	433	1 853	+ 5	455	2 047	10 235	409 400
Gikongoro	160	128	362	+ 4	133	399	1 995	79 800
Ruhengeri	93	74	162	+ 3	77	231	1 155	46 200
Byumba	183	146	663	+ 4	151	755	3 775	151 000
Kibungo	40	32	85	+ 3	33	99	495	19 800
Total	2 296	1 835	5 158	-	1 922	6 750	33 750	1 350 000

Notes: [a] It is expected that after the first year of the project 80 percent of the existing ponds will have been rehabilitated, and stocked with fingerlings

[b] Estimates, taking into account percentage of inhabitants involved in fish farming in each prefecture, situation of existing ponds and number of extension workers assigned to each prefecture

[c] Estimated as follows: average area of one pond is 3 ares in the prefectures of Kigali, Gitarama, Gikongoro, Ruhengeri and Kibungo; 4.5 and 5 ares respectively in the prefectures of Butare and Byumba

[d] Production based on an average yield of 5 kg fish/are/year (or 500 kg/ha/year)

[e] Calculation based on a stocking rate of two Tilapia nilotica fingerlings per m^2, or 200 fingerlings/are

Table 9

Expected Increase during a 4-Year Extension Programme

Prefecture	End of First Year[a]				Second Year			
	No. of ponds	Surface (ares)[b]	Fingerling requirements	Expected production (kg/year)[c]	No. of ponds[d]	Surface (ares)[b]	Fingerling requirements	Expected production (kg/year)[c]
Kigali	548	1 644	328 800	8 220	575	1 725	345 000	12 075

Gitarama	525	1 575	315 000	7 875	551	1 653	330 600	11 571
Butare	455	2 047	409 400	10 235	478	2 151	430 200	15 057
Gikongoro	133	399	79 800	1 995	140	420	84 000	2 940
Ruhengeri	77	231	46 200	1 155	81	243	48 600	1 701
Byumba	151	755	151 000	3 775	159	795	159 000	5 565
Kibungo	33	99	19 800	495	35	105	21 000	735
Total	1 922	6 750	1 350 000	33 750	2 019	7 092	1 418 400	49 644

Prefecture	Third Year				Fourth Year			
	No. of ponds[d]	Surface (ares)[e]	Fingerling requirements	Expected production (kg/year)[c]	No. of ponds[f]	Surface (ares)[g]	Fingerling requirements	Expected production (kg/year)[c]
Kigali	604	2 416	483 200	24 160	664	3 320	664 000	49 800
Gitarama	579	2 027	405 400	20 270	637	3 185	637 000	47 775
Butare	502	2 510	502 000	25 100	552	2 760	552 000	41 400
Gikongoro	147	515	103 000	5 150	162	810	162 000	12 150
Ruhengeri	85	255	51 000	2 550	94	470	94 000	7 050
Byumba	167	835	167 000	8 350	184	920	184 000	13 800
Kibungo	37	111	22 200	1 110	41	205	41 000	3 075
Total	2 121	8 669	1 733 800	86 690	2 334	11 670	2 334 000	175 050

Notes: [a] It is assumed that after the first year of the project 80 percent of the existing ponds will have been rehabilitated, and stocked with fingerlings

[b] Estimated as follows: average area of one pond is 3 ares in the prefectures of Kigali, Gitarama, Gikongoro, Ruhengeri and Kibungo; 4.5 and 5 ares respectively in the prefectures of Butare and Byumba

[c] Production targets are as follows: first year, 5 kg fish/are/year; second year, 7 kg fish/are/year; third year, 10 kg fish/are/year; fourth year, 15 kg fish/are/year

[d] Annual increase is assumed to be 5 percent

[e] Estimated as follows: average area of one pond is 3 ares in the prefectures of Ruhengeri and Kibungo; 3.5 ares in the prefecture of Gikongoro; 4 ares in the prefecture of Kigali, and 5 ares respectively in the prefectures of Butare and Byumba

[f] Annual increase is assumed to be 10 percent

[g] It is assumed that the surface of all the ponds is 5 ares (= 500 m^2)

(ii) During the four years of the project, sixty field extension workers (moniteurs piscicoles) should be trained 15 to 20 at a time in courses lasting four months. They should be recruited from people who have a primary education followed by several years of intermediate vocational training at a Rural Training Centre; they should be able to read and write Kinyarwanda and preferably should understand some French.

Each moniteur piscicole should be equipped with a bicycle or motor bicycle; protective boots; survey tape; mason's level; pegs and cord; note books; ruler; pencils, etc.; spring balance (to 10 kg); bucket; scoop net; beach seine (10 m) and cast net; audio-visual and other aids to disseminate information; including slide projector, portable screen, slides, portable generator or other source of power, booklets, posters, etc.

The duties of the moniteur piscicole would include:

- familiarizing himself with the parts of his district that have been identified (by expert survey, water flow measurements and soil analysis, if necessary) as suitable for fish farming;

- identifying farming families willing to participate in the project;
- advising and assisting in pond layout, construction, liming, etc.;
- arranging for supply of fingerlings and stocking of ponds;
- demonstrating and monitoring culture operations;
- arranging for supplies of fertilizer and feed as may be decided;
- advising and assisting at harvest, and in marketing of surplus;
- recording inputs and outputs;
- providing feed-back information to the prefectural centre regarding results, problems and attitudes;
- assist in passing on requests and suggestions from local to prefectural level;
- assist in applications for and distribution of any subsidies or other assistance available;
- carrying out local promotional activities for fish consumption and fish farming.

6.4.3 Fish breeding stations

i. As already mentioned (5.4.3 above) ponds at the breeding stations are too large. Ponds for fingerling production should be around 100 to 400 m^2 each.

ii. Facilities at Kigembe will have to be extended and upgraded to accommodate the training courses for moniteurs piscicoles. A dormitory block (100 m^2), a kitchen (40 m^2) and a hall (80 m^2) to serve as a refectory, classroom and recreational space will be needed.

6.4.4 Fingerling production

One of the main bottlenecks in development of aquaculture in Rwanda is the all-year round availability of fingerlings of suitable fast growing species for pond culture. At present only few fingerlings of T. rendalli and T. macrochir are available at the Kigembe Centre.

Tilapia nilotica is recommended as the main species, and breeding ponds should be stocked, in monoculture, at a density of 2 fingerlings/m^2 (or 200 fingerlings/are). The number of T. nilotica fingerlings required during the first year of the project in each prefecture are given in Table 10. The fingerling requirements for the four years of the proposed programme are indicated in Table 9.

Fingerlings of other species, required for polyculture, will have to be produced in due course as and when systems suitable for Rwandan conditions are identified by practical trial and demonstration.

Table 10

Requirement for Fingerlings and Corresponding Pond Area First Year of Programme

Prefecture	No. of fingerlings needed[a]	Brood stock needed		No. of fingerlings produced/year[d]	Required surface area	
		Females[b]	Males[c]		Breeding ponds (ares)	Fry rearing ponds (ares)
Kigali	328 800	183	79	329 400	14	150
Gitamara	315 000	176	76	316 800	13	145
Butare	409 400	228	98	410 400	17	185

Gikongoro	79 800	45	19	81 000	4	37
Ruhengeri	46 200	26	11	46 800	2	21
Byumba	151 000	84	36	151 200	6	70
Kibungo	19 800	11	5	19 800	1	9
Total	1 350 000	753	329	1 355 400	57	617

Notes: [a] Fingerling requirements: calculations based on a stocking rate of two Tilapia nilotica fingerlings/m^2

[b] Number of T. nilotica females needed to produce the required fingerlings

[c] Number of T. nilotica males according to a ratio of 1 male for 2 females

[d] Number of fingerlings calculated as follows: from each female one obtains annually 2 000 fry. With a 10 percent mortality rate during a two-months rearing period about 1 800 fingerlings per female will be available for stocking purposes

6.4.5 Research and development

It will be desirable to carry out simple practical trials of the following aquaculture techniques: (i) polyculture in ponds of Tilapia nilotica, T. rendalli, T. melanopleura and T. macrochir at different densities with artificial feeds and fertilization of ponds; (ii) polyculture in ponds of T. nilotica + T. rendalli + T. macrochir + Clarias mossambicus (as predator) with artificial feeds and fertilization of the ponds; (iii) trials, in polyculture, of application of lime at different rates; (iv) trials, in polyculture, of application of compost; (v) trials, in polyculture, of application of inorganic fertilizers such as triple superphosphate, ammonium sulphate and urea; (vi) trials concerning associated animal husbandry (fish-cum-pig culture, fish-cum-duck culture and fish-cum-chicken culture). These trials should be carried out at Kigembe or other suitable locations within easy access, as may be decided after consultation between the national programme leader and the international experts attached to the project.

The results of these investigations should be demonstrated and introduced to rural fish farmers as and when seems opportune and desirable.

6.4.6 Administrative and practical support

In the early stages of the programme, special provision may have to be made for procurement and delivery of certain inputs and for marketing of the produce until a sufficient number of farmers have adopted the improved technique to justify the establishment of permanent fullscale arrangements: for example, procurement of certain types of material for supplementary feeds, or marketing of a large crop of fish at a reasonable price. In these early stages, the programme may need additional temporary assistance (short-term consultancies), financial assistance or special facilities to ensure that the innovation does not fail because the fullscale system of support and marketing does not yet exist; the extension workers will also need official backing at senior level to overcome unforeseen administrative problems.

6.4.7 Promotional activities

i. The consumption of fish should be encouraged through local demonstrations, publicity, inclusion of fish in the diets in residential schools, training centres, hospitals, the armed forces and so on.

ii. Fish farming should likewise be publicised; it should be included as a subject in the curricula of schools, youth training centres and so on.

iii. Provision should be made for such activities in the course of the four-year programme and an official of the Ministry designated as responsible for their effective execution.

iv. The Government, and the official responsible, should however, bear in mind that premature publicity can be counter-productive. There is no point in advertising fish unless it is available. There is even less point in advocating allocation of land and effort to fish farming unless and until it can be demonstrated to the satisfaction of small-scale farmers that it is worth their while. The official responsible for promotional activities should therefore liaise closely with those responsible for the development programme and should coordinate his activities with those of the project, timing them according to the progress actually achieved.

6.5 International Technical Assistance

6.5.1 The services of at least two international experts in aquaculture should be provided for the duration of the project. One would concern himself mainly with training fingerling production and experimental trials, the other with the activities of the field extension workers. Both should have experience of fresh water aquaculture in tropical Africa and a record of achievement in their respective fields. They should preferably be fluent in French.

6.5.2 To assist in the field programme and in the popularisation of fish in the diet and of fish farming, the services of a number of international volunteers or associate experts financed by their home governments under the auspices of the project should be sought.

6.5.3 The project budget should also include provision for consultancies in order to provide appropriate expertise required only for short periods; to enable any unforeseen technical problems to be overcome; and to facilitate the exploitation of unforeseen opportunities. A total of say sixteen three-month consultancies should be provided for.

6.5.4 Considerable flexibility will have to be provided in the work plan and budget to allow for various possible developments that practical experience may indicate to be necessary or desirable; for example, for pond construction in some types of peat; pond fertilization; processing and transport of supplementary feeds; acquisition of brood stock, fry or eggs of various species; investigation and development of various systems of culture that may be recommended or seen to be worthy of trial at the time. See 6.4.6 above.

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7. FARM-LEVEL FINANCIAL ANALYSIS

7.1 General Considerations

7.1.1 For aquaculture ventures it is possible to relate operational inputs to expected outputs with a reasonable probability. In assessing the financial feasibility of aquaculture development on a micro, i.e., individual farm level, it is necessary to estimate or predict the general and seasonal availability and costs of the projected inputs and compare them with expected revenues. From the farmer's point of view, the revenues must be compared with the benefits which could be derived from alternative farming operations using the same land or labour, in order to arrive at a conclusion regarding the desirability of engaging in aquaculture. A reliable appraisal of this kind can be made only when sufficient practical experience has been gained of the systems under consideration. What follows is therefore only a preliminary assessment based on estimated costs and earnings for aquaculture.

7.1.2 It has to be borne in mind, moreover, that the decision to culture fish has to be made by the farmer and his family and they have to bear the consequences; values and priorities may be different from those implied in the kind of analysis attempted here. The socioeconomic and socio-cultural variables, which will be discussed in Chapter 9, will be of at least equal importance.

7.2 Factor Analysis

7.2.1 Land and water

Decisions on land-use will be made by the farmers on an individual basis. General land availability has been discussed in 3.3. above.

Rainfall can be used as an indicator for water availability (see 3.1.2). However, water availability should be assessed individually for each envisaged operation. As a general rule, pond culture of fish requires a water inflow of 9 1/sec for a pond of 1 ha with an average depth of 1 m to offset seepage and evaporation.

No overall statement on the quality of available land and water can be made here. For each envisaged fish pond topography, soil and water quality and accessibility have to be studied. Decisive factors are usually pH value, mineral contents and the capability of the soil to hold water. Particularly the available marshland, with obvious potential for pond culture, will have to be examined carefully in this respect (acidity). See 5.1 and Annex 3.

7.2.2 Opportunity costs of land

From an economic, as well as from a financial point of view, it would be ideal to use land which is more or less unsuitable for agriculture as little or no opportunity costs arise in such cases. As implied earlier (3.3) however, aquaculture will often have to compete with agriculture for land. It is assumed that farmers will not buy or lease additional land for aquaculture, at least in the near future. Nevertheless the alternative possible and probable land use under the prevailing production structure will have to be taken into account. Swampy marshlands (marais) for example, will have the opportunity cost of the gross value of crops presently grown, minus inputs, for the respective land area and over a given time. The ‘marais’ are typically farmed under the following production pattern (for 1 ha/year):

Table 11

Structure, Output and Value of Present Marshland Production

Crops	Area (m^2)	Percentage of area	Production (kg)	Price/kg (Rw.F.)	Value (Rw.F.)
Sweet potatoes	6 000	60	2 700	13	35 100
Beans, interplanted with maize	3 000	30	270 300	30 10	8 100 3 000
Green fodder	1 000	10	600	2	1 200
Total					47 400

Inputs to be deduced from the total value created by marshlands cultivated in the way shown above are almost entirely farm labour. Farm labour is difficult to value for rural subsistence production, ranging from zero (when no alternative production is possible) to the monetary return on labour for an alternative activity, which can be as high as Rw.F. 528/man/day (IBRD, 1977) in the case of banana cultivation.

For the opportunity cost of marshlands considered for fish culture, the labour input, which has to be subtracted from the total value of production, should be calculated according to estimates of the value of production (per ha/year):

Table 12

Labour Requirements of Present Marshland Production

Crops	Area (m^2)	Percentage of area	Labour Input (man/days/year)	Returns (per man/day) (Rw.F.)	Total (Rw.F.)
Sweet potatoes	6 000	60	180	103	18 540
Beans, interplanted with maize	3 000	30	35	97	4 000
Green fodder	1 000	10	20	40	800
Total			235		23 340

Source: Based on IBRD, 1977 and estimates of the author

On these assumptions, the opportunity cost of marshlands can be roughly estimated at Rw.F. 24 000/ha/year (total production - labour inputs).

7.2.3 Labour

Together with land and water, labour is one of the most important inputs in rural aquaculture.

(i) Labour potential

The dominant agricultural production unit is the nucleus family (parents, children) with additional inputs from the aged and the unmarried brothers or sisters. Average family size is about five persons (4.71 in 1970, 4.97 in 1973) constituting a total labour potential per family of about 4 000 hours or 660 man/woman days a year (Delepierre et al., 1978).

(ii) Seasonality of farm labour inputs

Because of the variety of food and cash crops cultivated simultaneously by the average Rwandan family, labour inputs are spread relatively evenly throughout the year (see Table 13). Occasional labour peaks occur, however, but usually neighbourhood and kinship help are available in such cases.

The following diagram shows the seasons of production of marshland crops[1]:

[1] That is to say, beans are under cultivation from July to October; green fodder is produced all the year round

Fish culture operations will have to be timed in order to avoid coinciding labour peaks. This implies planning for major labour inputs in fish culture during the months January to May, and, to a lesser extent, October and November, in order to prevent labour peaks coinciding with present 'marais' cultivation patterns. An indication of the seasonality of labour inputs for the overall farm production pattern is given, for one region, in the table presented below:

Table 13

Annual Calendar of Farm Work at Butare

September	Sowing of beans and gourds; cultivation of the hillsides
October	Further sowing of beans; planting of potatoes and sweet potatoes; harvesting of beans and sweet potatoes grown in the marshes
November	Weeding work in the banana groves; harvesting the leaves of beans and pulses; planting of banana trees
December	Harvesting the first potatoes and the first green beans
January	Harvesting of beans; preparation of the mixed crops of sorghum, beans, maize, and sweet potatoes under the banana trees and of the fields of peas, beans, and sorghum in the open air
February	Harvesting of potatoes; continuation of the sowing of beans, peanuts and sorghum, etc.; planting of sweet potatoes and pulses; harvesting of gourds
March	Planting of potatoes and sweet potatoes
April	Harvesting of green beans
May	Harvesting of beans and maize
June	Preparation of the marshes for the planting of sweet potatoes; beginning of the sorghum and coffee harvest
July	Harvesting of peas, potatoes, coffee; storage of sorghum; threshing of dried beans; mulching of coffee trees
August	Reconstruction of huts; brewing; marriages
All year round	Care of banana groves, preparation of banana beer and harvesting of fruits; harvesting and preparation of manioc; harvesting of sweet potatoes; care of animals

Source: Leurquin (1960) In: Morris (1979)

(iii) Division of labour

As for the qualitative division of labour between the sexes the men usually perform the heavy works such as land preparation; they are also dominant in animal husbandry and take care of cash crops like coffee and (except for composting) banana cultivation. Women are mainly responsible for the daily labour for food crop production and the household. Harvesting and post-harvest activities are generally shared between the sexes. A quantitative breakdown of total weekly labour inputs is shown in Table 14.

Table 14

Average Hours Worked per Week

	Farm and associated	Off-farm		Household	Total/Week
		paid	not paid		
Household head	35.2	10.2	3.3	2.6	51.3
Wife	38.1	1.4	1.0	16.7	54.8
Son	25.4	11.4	2.1	5.6	44.5
Daughter	29.4	3.6	1.7	17.5	52.2

Source: Delepierre et al., 1978

For fish culture operations it would therefore seem convenient for pond construction and pond maintenance (earth work) to be done by the male family members and feeding/fertilizing by the women. Stocking, harvesting and post-harvest activities will probably be shared between the men and women.

(iv) Opportunity Cost of Labour

The family labour inputs of 4 000 man/hours/year/family indicate a high degree of utilization of overall available labour.[1] It appears to be advisable, therefore, to attach a value to labour input projections for fish culture.

From the calculation of opportunity costs for marshlands, as shown in the former chapter, one can deduct a return on labour per day of about Rw.F. 100 for marshland cultivation and this figure will be assumed for the micro-economic analysis presented here.

In cases where labour envisaged for fish culture has to compete with the alternative production of other agricultural commodities, the following table presents estimated returns on labour.

Table 15

Returns to Labour/Man/Day of Different Crops in Rwanda
(Rw.F.)

Crop	Returns/man/day undiscounted
Bananas	528
Peas	107
Groundnuts	168
Soybeans	91
Sorghum	117
Millet	-
Rice	105
Potatoes	144
Cassava	115
Squash	123
Coffee	79
Tea	98
Pyrethrum	57
Cinchona	363
Cotton	72

Source: IBRD, 1977

[1] H. Brandt (1979) estimates an African average of 900–1 000 man/hours per economically active person in agriculture per year

7.2.4 Capital

For small-scale family-based pond culture little or no capital investment is required. Pond construction will be done by manual labour provided by the family, relatives or neighbours, in which case no monetary compensation is usually given. In pond construction concrete is not commonly used at present. Operational inputs such as labour, compost and green manure will, in most cases, come from internal sources without monetary exchange. Only fingerlings and, in the case of integrated production, livestock, will have to be purchased, but expenditure will be minimal (at present a nominal charge of Rw.F. 1/fingerling is considered adequate by the Département des Eaux et Forêts). For larger production units, managed by groups and cooperatives, locally produced bricks and clay pipes can be used and only a little concrete is needed. Operational inputs will be discussed in the next chapter. It is not envisaged that infrastructural capital costs will be passed on to farmers.

7.2.5 Operational inputs

Inputs, other than those already discussed in the factor-analysis, will consist mainly of feeds (for larger production units) and fertilizers, for which availability and costs have to be discussed.

(i) Feeds

Family-based small-scale fish culture will, in most cases, use feeds available on the farm, i.e., kitchen scraps, wastes from the food and cash crops, draff from banana and sorghum beer, non-edible parts of farm-grown vegetables, etc., none of which will represent a cost to the farmer. Purchase of feed inputs should be considered only for large-scale fish culture operations because transport will be economic only for large amounts; in any event feedstuffs exist only in limited quantities in Rwanda. At present, mainly rice bran and slaughterhouse wastes are used in the few cases where fish are being fed. Agro-industrial wastes and by-products are, however, obtainable (see Annex 6). Little information on quantities, alternative uses, seasonality and prices is presently available; accordingly, the possibilities of using supplementary feeds will have to be evaluated for each colline and unit.

Presently available information indicates a cost price for the majority of brans of a maximum of Rw.F. 1/kg, while slaughterhouse and other wastes can be obtained free of charge. Accordingly, fish feed-based agro-industrial by-products and wastes, including transport, will be assumed for the present to have a cost price of about Rw.F. 2/kg, if available within a radius of no more than 50 km.

(ii) Fertilizer

Chemical fertilizer is presently not, or only marginally, available in Rwanda. Therefore, green manure and compost will have to be used for fertilizing the fish ponds; the availability of livestock manure will have to be assessed for each individual site.

For green manure, i.e., grasses, vegetable residues, other plants, which are available on a normal farm in Rwanda, no specific costs are assumed. The labour necessary to collect and apply it is part of operational labour inputs. For compost, which requires considerable labour inputs to prepare but is especially valuable, costs have to be taken into account, based on the opportunity cost of the labour necessary for compost production. For fertilizing a 1-ha pond, 20 to 30 tons of compost are necessary and the preparation requires 120 men/day approximately. Assuming that the raw material for compost preparation, i.e., all kinds of organic matters, grasses and crop wastes is available on the average farms at no extra cost, fertilization of 1-ha of pond for one year would cost about Rw.F. 12 000.

7.3 Estimates of Costs and Earnings

7.3.1 The foregoing analysis has, apart from discussing the general availability of the necessary production factors, assumed values (opportunity costs) for the different inputs. Relating projected inputs to estimated outputs will indicate the profitability of fish culture operations under local conditions. As the productivity of pond culture will vary from case to case, according to the skill of the farmer, the efficiency of the extension service and the specific availability of inputs/outputs will vary.

7.3.2 All inputs/outputs will be expressed in the calculations that follow in monetary terms, according to their assumed opportunity costs or present values, which in some cases have to be deduced owing to the largely non-monetary nature of exchange in rural Rwanda. Although this reduces the complexity of agricultural production within the rural milieu to mere cost benefits, it will indicate whether, financially, fish culture is profitable to the small-scale farmer.

7.3.3 Expenditures and revenues are projected for two types of model operation: a 500 m^2 family-run pond under fertilization with compost and a 5 000 m^2 collectively managed pond with feeding. The species cultured are assumed to be Tilapia nilotica with T. macrochir and T. melanopleura, stocked twice a year at a density of 2 fingerlings/m^2. Fertilizer and feed inputs are projected according to the factor analysis above; for feed inputs a food conversion rate (C.R.) of 10:1 was assumed, i.e., 10 kg of feed would produce 1 kg of fish.

Expenditures associated with pond construction are not included in this calculation.

For a 500 m^2 pond stocked with T. nilotica and using compost the following revenues and expenditures are projected:

Table 16

Revenue-Expenditure Projections for a 500 m^2 Family Pond

Production Levels	I 1 000 kg (ha/y)	II 1 500 kg (ha/y)	III 2 000 kg (ha/y)
(a) Revenues			
- production per 500 m^2/year (kg)	50	75	100
- value per 500 m^2 (Rw.F. 75/kg)	3 750	5 625	7 500
(b) Expenditures (Rw.F.)			
- opportunity costs of land	1 200	1 200	1 200
- opportunity costs of labour (stocking, maintenance, harvesting)	1 500	1 500	1 500
- fingerlings	1 000	1 000	1 000
- compost	600	600	600
Total	4 300	4 300	4 300
(c) Net return (Rw.F.)	- 550	1 325	3 200

It should be noted that the only cash expenditure incurred by the family is the cost of fingerlings. If the farmer can be given sufficient training to keep the necessary number of fingerlings from the previous harvest, these costs would arise only once for initial stocking. On these assumptions, i.e., valuing all inputs according to their opportunity costs and purchasing fingerlings once a year, family fish farming of a 500 m^2 pond will break-even at a production level of 57 kg/year (1 150 kg/ha/year).

For a 5 000 m^2 pond stocked with T. nilotica, with feeding of rice bran and slaughterhouse wastes, a higher productivity can be expected.

Table 17

Revenue-Expenditure Projections for a
5 000 m^2 Collectively Operated Pond with Feeding

Production Levels	I 1 500 kg (ha/y)	II 2 000 kg (ha/y)	III 2 500 kg (ha/y)	IV 3 000 kg (ha/y)

(a) Revenues				
- production per 5 000 m^2/year (kg)	750	1 000	1 250	1 500
- value per 5 000 m^2 (Rw.F. 75/kg)	55 250	75 000	93 750	127 500
(b) Expenditures (Rw.F.)				
- opportunity costs of land	12 000	12 000	12 000	12 000
- opportunity costs of labour (stocking, maintenance, feeding, harvesting)	15 000	17 000	19 000	21 000
- fingerlings	10 000	10 000	10 000	10 000
- feeds (including transport, C.R. 1:10)	15 000	20 000	25 000	30 000
Total	52 000	59 000	66 000	73 000
(c) Net return (Rw.F.)	3 250	16 000	27 750	54 500

Calculated on a per ha per year basis, the break-even production would be 690 kg at the lowest intensity of cultivation, 786 kg at the next, 888 kg at the third, and 973 kg at the highest level of inputs examined.

7.3.4 From the foregoing figures, valuing all inputs according to their opportunity costs, and making deliberately unfavourable assumptions, fish farming will be profitable in itself if a production of about 1.2 t/year/ha can be achieved.

7.4 Comparison of Marshland Cultivation with and without Fish Farming

7.4.1 The comparison of marshland cultivation under the present production pattern and when used for fish culture allows a quantitative judgement on whether the latter offers a better return on land and labour to the farmer. For the 'with and without fish farming' comparison, no opportunity cost for land is considered in either case, but depreciation of initial investment for pond construction over 25 years is included. Initial investment for pond construction is depreciated linearly but no interest is added as inputs are almost entirely non-monetary, i.e., manual labour is provided by the family or the cooperative members.

Table 18

Volume and Value of Marshland Production With and Without Fish Farming
(Yearly Cost/Benefits for 500 m^2 with Fertilization)

Without Fish Farming					With Fish Farming (at medium productivity, 1 500 kg/ha/year)				
Production	area (m^2)	volume (kg)	unit price (Rw.F.)	value (Rw.F.)	Production	area (m^2)	volume (kg)	unit price (Rw.F.)	value (Rw.F.)
Sweet potatoes	300	135	13	1 755	Fish	500	75	75	5 625
Beans, interplanted	150	13.5	30	405					
with maize		15	10	150					
Green fodder	50	30	2	60					
Total				2 370	Total				5 625
Expenses	Quantity of Inputs		unit price (Rw.F.)	value (Rw.F.)	Expenses	Quantity of Inputs		unit price (Rw.F.)	value (Rw.F.)
Seeds	-		-	-	Seeds	1 000 fingerlings		1	1 000
Fertilizer	-		-	-	Fertilizer	1.5 tons		400	600

Labour	12 man/days	100	1 200	Labour	15 man/days	100	1 500
Depreciation	-	-	-	Depreciation	-	-	440
Total			1 200	Total			3 540
Gross return			2 370	Gross return			5 625
Net return			1 170	Net return			2 085
Gross return per man/day			197.5	Gross return per man/day			375
Net return per man/day			97.5	Net return per man/day			139
Rate of return			~ 97%	Rate of return			~ 59%
Gross return per ha			47 400	Gross return per ha			112 500
Net return per ha			23 400	Net return per ha			41 700

Table 19

Volume and Value of Marshland Production With and Without Fish Farming
(Yearly Cost/Benefits for 5 000 m^2 with Feeding)

Without Fish Farming					With Fish Farming (at medium productivity, 2 000 kg/ha/year)				
Production	area (m^2)	volume (kg)	unit price (Rw.F.)	value (Rw.F.)	Production	area (m^2)	volume (kg)	unit price (Rw.F.)	value (Rw.F.)
Sweet potatoes	3 000	1 350	13	17 550	Fish	5 000	1 000	75	75 000
Beans, interplanted	150	135	30	4 050					
with maize		150	10	1 500					
Green fodder	500	300	2	600					
Total				23 700	Total				75 000
Expenses	Quantity of Inputs		unit price (Rw.F.)	value (Rw.F.)	Expenses	Quantity of Inputs		unit price (Rw.F.)	value (Rw.F.)
Seeds	-		-	-	Seeds	10 000 fingerlings		1	10 000
Feed	-		-	-	Feed	10 000 kg		2	20 000
Labour	120 man/days		100	12 000	Labour	170 man/days		100	17 000
Depreciation	-		-	-	Depreciation	-		-	4 400
Total				12 000	Total				51 400
Gross return				23 700	Gross return				75 000
Net return				11 700	Net return				23 600
Gross return per man/day				197.5	Gross return per man/day				441.2
Net return per man/day				97.5	Net return per man/day				138.8
Rate of return				~ 97%	Rate of return				~ 46%
Gross return per ha				47 400	Gross return per ha				150 000
Net return per ha				23 400	Net return per ha				47 200

7.4.2 Although these figures are self-explanatory, it should be noted that for the 'with fish farming' calculations, all inputs have been valued according to their real or opportunity costs and only a moderate output is assumed. For the 'without fish farming' only the operational labour inputs are inserted as costs. In spite of this purposely applied bias, projected fish culture compares favourably with present marshland production, namely by producing more value from existing resources (land, water, labour, etc.), as demonstrated by the incremental values shown below (neglecting fingerling and feed costs).

Table 20

Incremental Values produced by Projected Fish Pond Operations as compared to Present Marshland Cultivation
(Rw.F./ha/year)

	Gross Return	Net Return	Gross Return (man/day)	Net Return (man/day)
Family units	+65 100	+18 300	+177.5	+41.5
Cooperative units	+102 600	+23 800	+243.7	+41.3

7.5 Comparative Returns from Fish and Other Crops

7.5.1 As shown in the foregoing, fish farming compares favourably with agriculture on marshlands. In the following table the projections of fish culture operation under local conditions will be compared with the average cost-benefit performance of food and cash crops presently grown in Rwanda. In the case of most of these crops, no competition for land use with fish culture will emerge. The relatively high grade of utilization of the labour potential of the family indicates, however, a possible conflict with respect to labour use. Therefore, comparing yields, returns, labour requirements and returns to labour, will allow to estimate whether, and to what extent, fish farming is beneficial to the farmer.

Table 21 shows that only banana production would yield a better return per man per day than fish culture and that only cinchona production would result in gross returns superior to fish culture.

With respect to the income generating capacity of fish culture it is useful to compare net return and cash return (percentage of return commercialized) of sweet potatoes, cassava, maize and beans, which are presently grown in marshy land, with the corresponding figures estimated for fish culture.

In addition, Table 22 shows the respective figures for rice and tea, cash crops which are to a very limited degree grown in the same environment at the moment and can be considered as possible alternatives to fish culture.

Table 21

Economic Performance of Different Food and Cash Crops as compared to Fish Raised in 500 m^2 Family Pond and in a 5 000 m^2 Cooperative Pond

	Fish 500 m^2	Fish 5 000 m^2	Banana	Beans	Peas	Cassava	Potatoes
Gross production (kg/ha/year)	1 500	2 000	9 100	800	800	4 100	6 600
Gross return (Rw.F./ha/year)	112 500	150 000	58 130	16 000	16 000	28 700	46 200
Labour requirements (man/days)	300	340	110	150	150	250	320
Gross return to labour (man/days/Rw.F.)	375	441	528	107	107	115	144

Sweet potatoes	yams	sorghum	maize	millet	wheat	rice	cinchona	tea	coffee	cotton	Pyrethrum
7 750	5 620	1 080	1 070	560	840	2 480	2 129	3 518	610	626	2 275
31 000	39 340	19 850	8 560	5 600	12 600	42 160	248 417	31 670	39 676	9 390	27 300
300	320	170	100	100	130	400	684	323	501	130	479
103	123	117	86	56	97	105	363	98	79	72	57

Source: IBRD, 1977 and own estimates

Table 22

Comparison of income generating performance of fish culture and alternative marshland crops (ha/year)

	Net Return	Gross Return	Percentage Commercialized	Cash Return	Cash Returns from 20 Family Ponds	Cash Returns from two Cooperative Ponds
Fish culture	41 700[1]	112 500	40	45 000	-	-
Sweet potatoes	28 500[1]	58 500	10	5 850	11 250	15 000
Cassava	3 700[1]	28 700	6	1 722	6 750	9 000
Maize	- [1]	8 560	9	770.4	10 125	13 500
Beans	1 000[1]	16 000	12	1 920	13 500	18 000
Rice	2 160[1]	42 160	80	33 728	90 000	120 000
Tea	- [1]	31 670	100	31 670	112 500	150 000

[1] Gross return minus labour inputs valued at Rw.F. 100/man/day

Source: IBRD, 1977 and own estimates

7.5.2 As inputs subtracted from the gross return in order to arrive at the net return are almost entirely non-wage labour, i.e. non-monetary inputs, net returns indicate mainly the profitability of the different operations. For an indication of the total potential income the gross return is significant; for an indication of the probable cash income the value of the average percentage of the production projected to be marketed (for fish) should be the preferred criterion. What percentage of the yearly fish production will be marketed by the farmer or the cooperative is difficult to project, therefore different degrees of commercialization have been assumed.

7.5.3 By allowing the farmer's family to eat 50 g of fresh fish twice a week, the yearly consumption per family would be 26 kg, leaving about 65 percent of the estimated production from a 500 m^2 pond to be marketed. If each family member consumed 50 g of fresh fish (or its processed equivalent) five times a week (per caput yearly consumption of 13 kg/year), still 15 percent of the total production could be marketed. Assuming a medium degree of commercialization of 40 percent, a 500 m^2 pond, covering 5 percent of an average farm, would yield a cash income of Rw.F. 2 250, using about 4 percent of the available labour.

7.6 Cash Flow Analyses

7.6.1 For calculation of the cash flow the cost for pond construction can also be estimated, although the non-monetary nature of inputs and the only partly monetary nature of outputs limits its significance. Here again, labour, which is the only significant input, will be valued according to its opportunity cost, i.e., Rw.F. 100/man/day. For a rough estimate of the labour effort needed for pond construction, 20 man/days to build 100 m^2 of pond with a medium depth of 1 m is assumed, plus 10 percent (2 man/days) for feeder canals. According to this estimate a hectare of fish pond would cost approximately Rw.F. 220 000 (Rw.F. 11 000/500 m^2, Rw.F. 110 000/5 000 m^2), which corresponds with pond construction costs in similar areas of Central Africa.

Table 23

Cash Flow of Rural Fish Culture over 25 Years (Rw.F.)

Year	500 m^2 Pond			5 000 m^2 Pond		
	Benefits	Costs	Cash Flow	Benefits	Costs	Cash Flow
1	2 812.5	12 550	- 9 737.5	37 500	133 500	- 96 000
2–25	5 625	3 100	2 525	75 000	47 000	28 000

7.6.2 The cash flow analysis shows an Internal Rate of Return of 25.8 percent for a family unit and 29.1 percent for the 5 000 m^2 unit. The initial investment for pond construction would be recovered within the fifth year of production (i.e., pay-back is five years).

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8. MACRO-ECONOMIC ASPECTS

The previous chapter considered the likely effects of the proposed development on the financial prosperity and standard of life of the individual farming family. This chapter discusses some of the longer-term economic implications and consequences of the proposed development from the point of view of the Government (the immediate requirements for Government action if the proposed programme of development is adopted, have already been described in 6.4 above).

8.1 Costs and Benefits to the Economy

It is desirable to predict the economic input/output dynamics of the situation expected to arise as a result of the proposed project activities and the possible impact on the national economy. Costs and benefits accruing to the economy and society through the development of rural fish culture cannot be assessed at the present time by means of a formal analysis. The necessary data are in part not available and many indirect effects are difficult to quantify. The project to initiate and support the proposed development is still in the formulation phase, which makes it difficult to project inputs and outputs. It is however, possible to outline some already predictable direct and indirect effects and implications of such a development effort, of concern to the Government.

8.2 Infrastructure

8.2.1 Because of the dispersed settlement structure in Rwanda, it will not be feasible to centralize support for the development of small-scale rural fish culture with respect to operational inputs. Material inputs which are not available on the farm comprise feed and fingerlings. Feed procurement, where planned, will have to be organized, for timely availability and transport, by the respective production units, and during the initial development phase producers will require advice and technical assistance from extension agents.

Initially fingerlings can be produced centrally, but with a growing geographical coverage of the development programme, fingerling production and distribution will have to be organized on the prefectural level. The present transport and communication system in rural Rwanda constitutes, in general, no constraint to the physical infrastructural support, as most settlements can be reached by earthen roads which are passable most of the year.

8.2.2 Considering the degree to which farm produce may be consumed on the farm (although pond fish culture may result in a higher percentage of market production because of output peaks two or three times a year) and the relatively developed accessibility of rural markets, no difficulties can be foreseen at the moment with respect to marketing the surplus fish that the farmer has when he harvests his fish pond. Bulk harvests from larger scale cooperatively undertaken pond culture may, however, require the organization of transport of the product to urban markets and the collection of feed.

For both family based and cooperatively organized production, commercialization of the marketable surplus will be, at least in the near future, carried out by the producers, as the magnitude of production, as well as the dispersed locations of production units, will probably not encourage marketing by intermediates or traders.

There are 275 permanent markets in Rwanda, frequented daily by about 60 000 people (Aubray, 1976). The accessibility of markets is illustrated in the following table:

Table 24

Time to Reach Nearest Market[1]

Travel Time (Hours)	Families	
	No.	%
Less than half	169	14
1/2 – 1 1/2	617	51
1 1/2 – 2 1/2	282	23
2 1/2 – 3 1/2	130	11
3 1/2 – 4 1/2	6	
Over 4 1/2	4	1
	1 208	100

[1] Sample survey by Leurquin (1960) In: Morris (1979)

Source: Morris, 1978

8.3 Constraints to Development

8.3.1 The major constraint to the development of rural fish culture - sufficient numbers of extension personnel with medium-level and practical training - will remain. To overcome this constraint, and despite what has just been said, centralized in-country training will be most desirable, because resource limitations will not allow dispersed installations. Centralized research facilities, capable of validating established systems of aquaculture in local conditions and adapting them as necessary, will be the most practicable for the same reason.

The existing fish culture centre in Kigembe near Butare, seems to be potentially suitable for the purpose of establishing a national centre for fish culture training and applied research.

8.3.2 A serious constraint to an increased per caput consumption of fish is the low purchasing power of the rural population. The commercialization of fish in rural markets, via monetary exchange, will be limited in the near future, as rural incomes cannot be expected to increase dramatically. Therefore planning for fish culture development with the aim of countering the deficit of animal proteins in the rural diet will have to envisage small, family-based units, which provide fish for home consumption, barter and, only on a limited scale, the market. Any marketable surplus, however, will, at least in the near future, be readily absorbed by the urban markets and rural centres.

8.4 Inputs

8.4.1 Suitable raw materials for fish feeds, although apparently available, may be limited in some areas, and little is known about the present alternative use, as no tradition of semi-intensive or intensive animal husbandry exists in rural Rwanda. The availability and accessibility of suitable feedstuffs will have to be investigated for each concrete case where a medium-scale production unit is planned and feeding is envisaged.

8.4.2 The input, which is at present not available on a significant scale, is fingerlings of the right species. The development of rural fish culture will depend on the production and distribution of fingerlings to the farmers, at prices within their financial possibilities.

8.5 National Impact of the Development Effort

8.5.1 Based on the rough projections above, fish culture development would have a direct effect on existing production structure of the following dimensions:

i. Provision of fish for human consumption - after four years the production of about 180 tons of fish would provide sufficient animal protein for around 2 400 rural families; an increase of per caput consumption to nearly 10 kg/year will still leave 40 percent of the fish to be marketed (around 80 tons).

ii. Income - 2 400 families engaged in fish culture would increase their cash income by Rw.F. 2 000 to 2 500, by selling about 40 percent of their fish production. The estimated combined additional income of about Rw.F. 6 million would strengthen the internal market of the country.

iii. Employment - the labour potential of around 2 400 families would be used more productively; cooperative production may create self-employment in Government settlement schemes or other rural centres.

iv. The overall agricultural production structure would be diversified.

v. Introduction of improved systems on the scale envisaged, utilizing mainly indigenous resources, can be expected to establish fish culture in the rural milieu of Rwanda, with potential for development to an extent where a significant proportion of the national requirements for animal protein can be satisfied.

8.5.2 The outlined magnitude of production does not consider the probable spread effect (or multiplier effect) of successfully operating fish culture units, which may induce more than the number of farmers or cooperatives estimated to take up fish culture. However, taking into account only the above number of production units, the achieved production will, by the fourth year, have already increased the present yearly supply of fish in Rwanda considerably, adding an annual value of over 12 million to the Gross Domestic Product.

8.5.3 The most important benefit, however, will be that mentioned earlier above: the establishment of a national capability to assess, adapt, develop and apply systems of aquaculture to the extent that may seem necessary and desirable in the light of the national economic situation at the time.

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9. SOCIAL CONSIDERATIONS

9.1 Method of Inquiry

The following assessment of some of the variables which determine the socio-economic and socio-cultural context into which it is proposed to introduce improved fish culture techniques has to be considered theoretical to the extent that it was not possible to conduct a field survey or an extensive socio-cultural study on rural Rwanda. It is based on the few available studies and on interviews with persons familiar with the local rural situation.

9.2 Land and Population

The central constraint to a dynamic rural development is the discrepancy between an increasing population and finite land resources (3.2, 3.3). The population growth rate over the last ten years is estimated at 3.8 percent/annum, including immigration (0.4 percent). The population density, as mentioned earlier, is the highest in Africa. Between 1970 and 1976 the Ministry of Planning estimated 43 000 newly created jobs, while 258 000 new job seekers were believed to have entered the market (IBRD, 1977). In comparison with the population the land resource base is scarcely adequate.

9.3 Socio-Economic and Socio-Cultural Aspects

The social structure of a stable rural society is the organizational reflection of the production structure under which the goods and material values necessary for the subsistence and satisfaction of the producers are generated. A change in the production structure of a social entity is likely to require or result in a change in its social organization, while social change may alter the organization of production.

9.3.1 Land ownership patterns were described in 3.3 above. With respect to fish culture development, the present land ownership structure is not expected to be altered nor does it need to be. On a long-term basis and if fish culture generates a large cash surplus for some industrious farmers, this could, however, accelerate the trend of land alienation noted in 3.3.4.

9.3.2 Kinship and neighbourhood ties within a locality, based on mutual assistance and communal organization of public works and social functions, have remained relatively intact. Within the family the farm labour is divided along sex lines, with banana cultivation, cash crop production and animal husbandry, as well as tasks requiring physical strength, being done by the men and food crop production being done by women. The World Bank quantified the system of division of labour as shown in the following table, stressing, however: 'that in practice there is no such thing as a homogeneous farm but merely a series of overlapping sub-systems' (IBRD, 1977).

A case study on the division of labour in the Byumba Prefecture produced the following break-down:

Table 25

Division of Labour

		Relative Importance (%)	Men	Women
(a)	Domestic activities	15.5	10	90
(b)	Processing activities	5.1	5	95
(c)	Marketing (markets)	1.2	51	49
(d)	Handicrafts	1.7	1	99
(e)	Animal husbandry	10.7	44	56
(f)	Food crops	34.5	21	79
(g)	Banana plantation	0.7	93	7
(h)	Coffee trees (some 200)	23.0	30	70
(i)	Outside work	7.6	66	34
Total		100.0	27	73
Sub Total (f + g + h)		58.2	25	75

The Bank remarks further that:

'Even if the work force is provided primarily by the family, the extent to which outside labour is obtained in the traditional form of mutual aid or on a wage-paying basis is by no means negligible (at Byumba 33 percent of families avail themselves of outside workers, averaging 34 days per production unit per annum), especially at the time of the principal bottleneck in the agricultural year, i.e., at plowing time in the main growing season of September to October. Mutual aid is practised both amongst relatives and neighbours.

A proportion of working hours, which may be substantial on some farms, is set aside for non-agricultural activities like handicrafts and trading' (IBRD, 1977).

9.3.3 There is no apparent reason at present to suppose that the socio-economic organization of the family farm and its place in kinship and administrative structures will be significantly affected by the introduction or reactivation of fish culture in the rural milieu. The social organization of the family does not have to be altered in order to include fish farming in the production pattern. Only the structure of labour inputs will be changed to a limited extent, as time has to be allocated to construct and operate the fish pond. Pond construction and management can be integrated into the existing system of division of labour, with the men doing the earth work, which requires a large amount of physical effort, and the women doing daily maintenance work, composting, feeding, etc. Harvest and post-harvest activities will probably be carried out by both men and women, as is presently done for other crops.

9.3.4 For the collective undertaking of fish farming (e.g., within the framework of the Government settlement schemes (paysannats)) considerable organizational efforts would be required. Although mutual aid is common among farmers and one day per week is usually spent doing communal work, collectively planned, implemented and operated fish culture represents a new concept of production. The priorities accorded to it by the local administration, the qualities of the extension service and above all, the innovative enterprise of the farmers themselves, will determine whether such an approach can be carried through successfully. In order to ensure assimilation and retention of knowledge and skills in their districts, sharing of experience, and continuity of effort, and to sustain interest through mutual help and encouragement, the extension workers should encourage the formation of groups or collectives.

9.4 Land Use; Leadership and Decision-Making

9.4.1 The present land use pattern in rural Rwanda is, apart from ecological parameters (soil quality, altitude, rainfall, etc.), determined by a number of socio-economically and socio-culturally based variables, as:

(i) Diversification of production

To cultivate a variety of food crops and to achieve self-sufficiency is seen as a risk-minimizing strategy by the farmer. In case one crop fails, the subsistence of the family can be maintained by other crops with similar nutritive value.

(ii) The pressure to produce cash crops, noted earlier above (3.3.6)

(iii) Status

As an inheritance from feudal times, the possession of cattle is still regarded as the highest status symbol. Cattle occupy grazing land but yield little economical return. They are used as dowry, giving status to both donor and recipient when exchanged. Banana and sorghum beer also serve as an exchange equivalent within social relationships; they are also used to compensate ex-farm labour inputs. By expanding his banana plantation a farmer increases his social status. Judging by its high exchange value, rural people grossly overestimate the nutritional value of beer (Ndengejeho, 1980).

(iv) Tradition

Traditionally cultivators, the Bahutu farmers are reluctant to adopt production concepts alien to agriculture. Animal husbandry, for example, plays only a very minor role in rural production, because regular feeding of livestock has never been practised. According to the survey of Ndengejeho (1980) a considerable number of his respondents believed that fish, kept in a pond, do not need food: they are believed to subsist on soil or water. Another example is the practice of confining chickens to a cage during the sorghum harvest, to keep them from feeding on the grains. Being given no other food many chickens starve to death during this time.

(v) Leadership and decision making

No pronounced internal leadership pattern exists in the rural society. Patrilinearly organized kinship groups had, and to a lesser degree, still have, influence only on land allocation and were the taxable entity during the feudal times. At present, and in line with the atomistic settlement structure, only one external authority, the Government, and its administrative bodies, exercise leadership above the family level. Within the family usually the senior male is formally in command, followed by his son. His wife, however, is rather autonomous in the spheres dominated by her, e.g., food crop production and the household. A man would have to ask his wife's permission before taking food from the household storage. In the absence of detailed studies on the present decision-making process, it may be assumed, therefore, that the farmer decides on farm affairs, other than day-to-day food crop production, but that his wife is likely to influence his decisions.

9.4.2 Thus:

i. Fish farming may be regarded by the farmer as a useful diversification of production. Ndengejeho (1980) indicates a high degree of interest in fish farming among his respondents.

ii. Initially, at least, fish farming should be actively promoted by the local Governmental authorities.

iii. Fish may acquire an acknowledged non-monetary exchange value, with a crop from one family pond being partly distributed among neighbours, and vice versa.

iv. Farm management practice should be promoted, at least initially, with emphasis on fertilization, similar to plant crop production, rather than on feeding, as in animal husbandry.

v. Those engaged in extension and promotional activities should address themselves to both the farmer and his wife.

9.5 Motivation and Mobility

9.5.1 The basis of a farmer's decision to engage himself and his family in fish farming may be influenced by primary and secondary motivation factors. The primary motivation may include the expectation that fish farming will diversify his production further; that he achieves a higher degree of self-sufficiency; that the nutritional standard of his family is raised; that his monetary income is raised, and that his social status is heightened if he can give fish to his neighbours, etc. The intensity of primary motivation to produce fish will be determined by the value which is commonly attached to fish as a produce. In the survey conducted by Ndengejeho (1980) in four communes, his respondents gave as the principal reason for their interest in fish culture the nutritive value of fish, i.e., they were interested to grow fish for home consumption. Income creation, by selling fish, was rated as secondary. Fish was, according to the survey, thought of as having about the same nutritive value as red meat. The principal reasons for not eating fish were stated as non-availability and high prices.

9.5.2 The same survey indicated that farmers would be willing to undertake fish farming if they were encouraged to do so, if given help and if the necessary inputs were made available.

9.5.3 Ndengejeho's survey indicated a considerable degree of occupational mobility among his respondents with regard to fish farming. His sample was, however, geographically limited. To what extent the innovative potential and the occupational mobility of farmers in other areas can be reinforced and directed toward fish farming will depend upon the performance of fish culture extension and support from Government bodies. Initially successful on-the-spot demonstration in the field and on selected fish farms will be decisive.

9.6 Socio-Economic Impact of Fish Culture Development

9.6.1 During the initial phase of fish culture development, only a small group of farmers will be affected, because infrastructural support will be limited at that stage and will require time to develop. Nevertheless, the initial 'target group' of farmers, their selection and the approach employed to extend assistance to them, will determine the future impact of the development effort.

9.6.2 The identification of the individual farmer to be approached should involve the following criteria:

i. whether the environmental conditions necessary for fish culture exist on the land he cultivates;

ii. whether his personal drive and interest is sufficient to engage himself, his family and, for pond construction, relatives and neighbours, in taking up fish culture successfully;

iii. whether the accessibility of his farm to neighbours and his social status justify the aspiration that his fish pond can serve as a demonstration unit, convincing as many people as possible of the worthiness of fish farming.

Careful selection of the target group in the initial phase of development will be the most important prerequisite for successful dissemination of the concept. Demonstrable success will be the best means to convince others of the worthiness of fish farming. Other measures can be product promotion by Government bodies, extension agents and media, media coverage in general, inclusion of fish-culture-related courses in the curriculae of educational institutions, etc. The degree of success to which such strategies can be employed will determine the quantity of impact fish culture development may have in Rwanda.

9.7 Summing-Up

9.7.1 The quality, socially and culturally, of change which can be expected as a result of the development, can be assessed here only in the broadest sense. Because in some ways it more closely resembles agriculture than animal husbandry (seed-time and harvest, fertilization), fish culture will not bring about much change in the existing behaviour and value patterns and will not require much effort to comprehend. Neither will it require a significant change of organizational and production structures. Depending on the extent to which they participate, it may better the rôle and status of rural women in the country.

9.7.2 If not extended to a sufficient number of farmers, it may, however, alter the structure of income distribution in the rural milieu by increasing the income and monetary potential of the farmers engaging in it successfully.

9.7.3 It is desirable to focus innovative efforts on existing cooperative organizations such as the Government-sponsored settlements or to encourage groups of farmers to cooperate in aquaculture.

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ANNEXES

ANNEX 1
Agricultural Regions of Rwanda

Region	Average Elevation (m)	Average Rainfall (mm)	Soil	Population (%)	Land (%)	Principal Crops	Quality
Imbo	1 100	1 200	Alluvial	.5	.7	Banana, manioc, beans, peanuts, sweet potato, cotton, rice, sugarcane, citrus	Excellent
Impara	1 700	1 400	Heavy red basaltic	3.6	6.8	Banana, beans, maize, sorghum, sweet potato, manioc, peanuts, coffee, tea, quinchona	Good
Boros of Lake Kivu	1 600	1 200	Shallow, silty-clay	3.9	2.7	Banana, beans, maize, sorghum, sweet potato, manioc, peanuts, coffee	Good to excellent
Lava	2 200	1 500	Volcanic	4.1	3.5	Banana, beans, maize, sweet potato, sorghum, peas, potato, pyrethrum, tobacco	Excellent
Congo-Nile ridge	2 100	1 600	Acid organic	14.2	17.0	Peas, maize, potato, eleusine, wheat, tea, sun-flower, wood	Average
Buberuka	2 000	1 200	Laterised	9.2	7.0	Banana, beans, sorghum, sweet potato, maize, potato, peas, wheat, barley	Good
Central plateau	1 700	1 200	Organic (various)	21.5	13.2	Beans, sorghum, maize, sweet potato, banana, taro, yam, coffee, soybean	Good
Dorsale granitic	1 500	1 100	Light, gravel	15.4	6.8	Banana, beans, sorghum, maize, sweet potato, yam, taro, peanuts, manloo,	Average

						coffee, livestock	
Mayaga	1 450	1 050	Clay from schists	13.3	14.1	coffee, beans, sorghum, maize, banana, sweet potato, manioc, peanuts, soybean	Very good
Bugesera	1 400	900	Strongly altered clays	1.9	5.3	Beans, sorghum, maize, bananas, sweet potato, manioc, peanuts, livestock	Poor
Eastern plateau	1 500	950	Laterised	9.1	13.4	Beans, sorghum, maize, bananas, sweet potato, manioc, peanuts, coffee	Average N Good S
Eastern savanna	1 400	850	Old soils, variable texture	3.4	19.6	Manioc, peanuts, beans, sorghum, maize, sweet potato, livestock, National Park	Very good

Source: Morris, 1979

ANNEX 2
Potential Demand for Fish according to Different Consumption Levels and by Prefecture

(in metric tons)

Gitarama	636 752	14 600	11 500	3 400	1 700
Ruhengeri	613 671	14 100	11 000	3 200	1 600
Kigali	558 438	12 800	10 100	3 000	1 500
Gisenyi	493 443	11 300	8 900	2 600	1 300
Byumba	491 459	11 300	8 800	2 600	1 300
Gikongoro	417 942	9 600	7 300	2 200	1 100
Cyangugu	357 956	8 200	6 400	1 800	900
Kibungo	328 874	7 600	5 900	1 800	900
Kibuye	303 891	7 000	5 500	1 600	800
Rwanda	4 924 113	113 100	88 600	26 000	13 000

Source: Reizer, 1975

ANNEX 3
Peaty Soils

Peat consists of organic black deposits composed of the remaining parts of plants, partially decomposed, and accumulated due to bad drainage conditions which inhibit their decomposition. The natural vegetation cover consists of hydrophilic plants and mosses. Peat is acid and deficient in minerals and nitrogen, but has a high carbon content.

Meyer, quoted by Van Wambeke (1961), has studied the reclamation of peaty soils. His main conclusions are as follows:

(i) In the large marshes, where peat up to several metres, sometimes even more than 10 m, is present, reclamation presents severe technical and economic problems, including the irreversible settling (compression) which occurs during drying.

Except for peaty soils enriched locally by volcanic ashes in North Rwanda, the peats are inert, of poor quality, and with a very low mineralisation[1] capacity and a C/N ratio of between 20 and 30. Such soils are of no interest for agriculture or fish farming, because of their very low mineral content. This is especially true for the swamps situated at high and medium-high altitudes.

(ii) With regard to the swamps with a peaty layer limited to a depth of 1 to 2 m, or where settling has already occurred, the problems differ according to the region:

a. In the high altitude swamps surrounded by poor grasslands the soils are cold (11 to 15°C) and very poor. They are generally covered by a vegetation composed of Miscanthidium violaceum. The only economical method of bringing about the rapid mineralisation of these peats is the 'veenbrandkultuur', i.e., calcination by fire.

   Fertilizing with manure gives good results; liming has irregular effects.

b. In the swamps of medium altitude, incineration does not seem necessary. However, the yields decrease rapidly 18 months after clearing. Trials have shown positive results with the use of manure.

c. In regions of low altitude, the depth of peat is between 70 and 80 cm; the loss after calcination, 50 to 65 percent. Trials carried out in the Luguma Swamp have clearly demonstrated that skillful regulation of the water level, thorough incineration of all aerial vegetation and rhizomes and good cultural practices, can make these organic soils productive.

d. The histosoils (or organic and peat soils) of the volcanic zones are more fertile.

When peaty soils have to be reclaimed for fish farming, the drainage has to be done slowly and progressively in order to avoid irreversible and undesirable changes in the structure and water relations. The water table may not be lowered more than 0.80 to 1.00 m below ground surface.

When fibrous peat occurs, the incineration of the superficial layers is recommended before or during drainage. These fibrous materials will be transformed into ash, and when mixed with the other layers the acidity will be slightly reduced.

[1] Mineralisation: the change from the organic state to the mineral state is, for example, the case in the nitrogen cycle, when nitrogenous organic material is transformed into ammonia

The correction of excessive acidity by liming facilitates the humification of the organic matter and nitrification. Nitrogen deficiency can be corrected by application of fertilizers. This, combined with liming, is the best way to ensure fertility, but due to the high costs of fertilizers in Rwanda, it is not certain that such treatment would be financially viable.

When contemplating fish farming, it is necessary to carry out a complete soil survey, including soil and water analysis, to establish the need for liming and fertilization of the ponds.

See also Annex 9.

ANNEX 4
Stocking Rates in Polyculture

The following combinations are recommended for trial:

i. Tilapia nilotica (phytoplankton feeders): 2 fingerlings/m^2 (200 fingerlings/are) + 1 fingerling/m^2 (100/are) of T. rendalli (herbivore) + 1 fingerling/m^2 (100/are) of T. macrochir (plankton eater and browser);

or ii. T. nilotica: 200 fingerlings/are + Clarias lazera or C. mossambica = 100 fingerlings/are;

or iii. T. nilotica: 200 fingerlings/are + T. rendalli = 100 fingerlings/are

To all these combinations, one should add about 10 Haplochromis mellandi or Astatoreochromis alluaudi fingerlings/are to control snail populations.

ANNEX 5
Combined Animal Husbandry and Fish Culture

Fish-cum-pig culture

Pigs are reared in pens built over the ponds on piles at a density of 100 pigs/ha (1 pig/are). Normally one sow produces three broods of 6 to 8 piglets each in two years. Thus, one can sell an average of 8 to 10 pigs/year/sow in reproduction. The piglets are weaned at two months (weight between 12 and 15 kg) and are ready for fattening. Castration has to be done at one month. With proper feeding the average weight of market pigs is 70 to 72 kg after six months and 85 kg at seven months.

In ponds stocked with Tilapia nilotica at a rate of 2 fingerlings/m^2, the average production of fish can reach between 8 000 and 10 000 kg/ha/year and 6 000 to 9 000 kg of pigs (on the hoof) per ha/year (Vincke, 1976).

Fish-cum-duck culture

Ducks are reared in pens over the ponds at a density of 1 000 to 1 500 ducklings/ha (10 to 15/are). Peking and Moscovy ducks are generally raised in Africa. The shelter, where ducks are fed and spend the night, is built over the pond on poles. The floor is made of lattice work to permit droppings and feed wastes to fall into the water. Under good conditions ducks reach 2 kg after 8 to 9 weeks.

Ponds are stocked with fish at the usual rate of 2 to 3 fingerlings/m^2 and production can reach 2

500 to 4 500 kg fish/ha/year and 1 500 kg of duck per ha/year.

For large-scale fish-cum-duck culture, a well-operated breeding and duckling distribution centre is needed. The production of ducklings is, of course, dependent upon the maintenance of an adequate brood stock (1 male to 4–6 females) of a selected strain. During one laying season and under good conditions a Peking duck will lay 120 to 160 eggs. During peak production, two eggs are laid every three days. One female duck will produce 70 to 80 one-day-old ducklings during a laying period of eight months under suitable conditions (Woynarovich, 1979).

ANNEX 6
Fingerling Production

The list of species that seems suitable for culture in Rwanda includes the following: Tilapia nilotica, T. rendalli (or T. melanopleura), T. macrochir, Clarias lazera, C. mossambica, Haplochromis mellandi, Astatoreochromis alluaudi and, eventually, common carp, grass carp and silver carp. The breeding stations should therefore be equipped to make available fingerlings of some or all of these species.

Small ponds (100 to 400 m^2) which can be drained quickly and easily are most suitable.

(a) Tilapia nilotica

Fingerling production of T. nilotica (natural spawning in ponds) is relatively easy and can be carried out in all breeding stations in the country. Those fish destined to become broodstock should be reared at a stocking rate of 2 fingerlings/m^2. Tilapia nilotica broodfishes should be stocked in spawning ponds of 1 to 4 ares (= 100 to 400 m^2 at a density of 14 females and 6 males/are, or 20 broodfishes per 100 m^2. Average individual weight of females will be around 150 g and for the males between 150 and 200 g.

Under Rwandan conditions each T. nilotica female might be expected to spawn about five times a year with an average of perhaps 400 fry per spawning. Each female would thus produce perhaps 2 000 fry/year. Assuming a mortality rate of 10 percent during a two-month rearing period, fingerling production of one female might be 1 800 one-month-old fingerlings per female and per year.

Spawning ponds should be fertilized using manure (3 to 5 kg/are every two weeks) or well decomposed compost (20 to 30 kg/are/month).

When harvesting the fingerlings, the spawning ponds should be drained the first time after three months and every one or two months afterwards, except in the cold season.

The small fingerlings should be stocked in fertilized growing ponds until big enough to be transferred to production ponds (8 to 10 g). The following fertilization can be applied:

- manure: 5 kg/are every two weeks, or
- compost: 20 to 30 kg/are/month

If inorganic (chemical) fertilizers are available at competitive prices, one could apply the following monthly: superphosphate: 0.400 kg/are + ammonia sulphate: 0.200 to 0.400 kg/are or urea: 0.100 to 0.200 kg/are + agricultural lime: 1 kg/are.

Stocking densities in growing ponds should be 500 fingerlings/are (or 5 fingerlings/m^2). Fingerlings will stay about two months in the growing ponds and should be fed daily. Some diets are described in Annex 8 of this report.

(b) Tilapia macrochir and T. rendalli (T. melanopleura)

Reproduction of these two species has to be done in the same way as for T. nilotica.

Tilapia macrochir is likely to spawn 4 to 5 times a year with an average of perhaps 500 fry per spawn. Tilapia rendalli is more prolific than the microphagous and planctonophagous T. macrochir and T. nilotica and may spawn 5 to 7 times a year with an average of perhaps 2 000 fingerlings/spawn.

(c) Clarias lazera and C. mossambica

If the various species of Clarias do not spawn naturally in ponds, induced spawning should be tried using hypophysis and desoxycorticosterone acetate.

(d) Haplochromis mellandi and Astatoreochromis alluaudi

For reproduction, these species have to be kept in separate spawning ponds to avoid cannibalism. Stocking rates should be around 20 adults (10 males and 10 females) per are.

ANNEX 7
Use of Agricultural and Industrial Waste Products for Supplementary Feeding

General

The deliberate feeding of fish benefits growth by supplementing the natural food present in the ponds. The feasibility of supplementary fish feeding in Rwanda depends, however, on the availability of cheap foodstuffs and agricultural by-products with a sufficiently high food conversion rate (CR).

Many of the wastes and by-products potentially suitable as feed are grown and processed in the vicinity of towns such as Gisenyi, Ruhengeri, Kigali and Butare, far away from most villages.

Diets for fish might be prepared using locally available feed stuffs which can be surface broadcast. Fish farms might, however, have to be equipped with grinders to allow the grinding of feed stuffs such as maize, cotton seed, etc., for preparing diets for fish.

Availability and use of wastes and by-products

The following agro-industrial by-products are available: draff (brewery waste), brewery yeast, draff from banana beer and sorghum beer, slaughter waste (blood, stomach contents and bones), rice bran and rice polishings, wheat bran and regrindings, sugar cane waste and molasses, household scraps, cassava waste, soybean cake, maize (grains, meal and bran) and coffee pulp.

Draff (beer waste): is produced as a by-product in the brewery industry at Gisenyi. The present production is 1 400 t/year approximately, and draff can be obtained free of charge. A new brewery will be established soon at Kigali. The conversion rate of draff, properly used, is 12:1 (12 kg draff is needed to obtain 1 kg fish). Up to 20 percent of draff can be used in fish feed, and up to 15 percent can be fed to pigs and ducks if associated animal husbandries and fish farming is envisaged. Tilapia nilotica stocked at a rate of 2 fingerlings/m^2 and fed only with wet draff supplied bi-weekly at a rate of two-thirds of estimated weight of fish population in the pond have been known to yield as much as 3 500 to 4 000 kg fish/ha/year.

Brewer's yeast: is an excellent source of protein of high nutritive value and digestibility. In poultry and pig rations it is generally included at levels of 2 to 5 percent (Göhl, 1975). Usually available as slurry, it has to be dried or cooked to de-activate the yeast cells. The brewery at Gisenyi produces 200 000 litres approximately of yeast (slurry) per annum, available free of charge. The total production is at present discharged into Lake Kivu.

Draff from banana beer: according to Morris (1979), the total banana production of Rwanda was 1 896 253 tons in 1978, at an average price of Rw.F. 700/kg. Between 36 and 100 percent (average 76.9 percent) of the banana production is utilized for the preparation of banana beer (the average consumption of banana beer is 281 kg/person/year (Morris, 1979)). One needs 2.5

to 3 kg of bananas to obtain 1 litre of beer. Banana beer is prepared in almost all villages, all the year round. About 987 000 000 tons of banana draff is available annually in the country, with a CR of 10:1 (10 kg of draff needed to produce 1 kg of fish). A 200 litre petrol drum, containing about 180 kg draff of locally made beer (banana or sorghum beer) can be bought in Butare for Rw.F. 300, and in Kigembe for Rw.F. 400 (between Rw.F. 1.67 and 2.22/kg draff).

Draff from sorghum beer: the sorghum production reached 163 776 tons in 1977 (Morris, 1979). When preparing beer 84.7 percent of the harvest is used (1 kg sorghum = 2 litres beer). The annual production of sorghum beer draff is about 20 800 tons, with a CR of 10:1. Draff of sorghum beer is available all the year round in almost all villages at little or no charge.

Slaughterhouse wastes: sheep, goats and cattle are presently sold in 60 traditional markets. They are slaughtered in three abattoirs (Kigali, Butare and Rusumo), 28 slaughter houses and 276 slaughter places (Morris, 1979). The waste is most often discharged into rivers. Slaughterhouse wastes include entire carcases of animals that have died from diseases; carcases or parts of carcases that do not pass inspection; fresh blood; inedible parts of the digestive tract; reproductive organs and bones and other trimmings not regarded as edible. Normally, in Rwanda, only blood, stomach contents and bones are available.

It is possible to utilize offal to feed fish, pigs and poultry. In diets based on cereal grains and other plant products, it is difficult to avoid a deficiency in essential amino acids and in some vitamins, and slaughterhouse waste can supply these amino acids and vitamins. Even when used in small amounts they vastly improve the nutritive value of the entire fish feed diet (Göhl, 1975).

a. Blood meal: contains only small amounts of minerals but is very rich in protein. However, it is of a rather inferior amino acid composition. The digestibility of raw blood is very high.

   Approximately 390 000 kg of raw blood is available annually in Rwanda. This quantity, if recovered, could be used as food for fish, pigs and poultry. Blood meal can easily be produced on a semi-commercial scale. The blood is collected at the abattoir and boiled very slowly in a large pot over an open fire until coagulated and the water evaporated. Continuous stirring is necessary. When coagulated, the blood is then spread onto a concrete floor or galvanized sheets, dried in the sun and then cooled off and dried completely in a well-ventilated shed. When completely dry, the blood meal is scraped off with a shovel and milled to obtain a black meal. According to Göhl (1975), 1 000 kg of liveweight carcass yields about 6 kg of blood meal.

   Another way to utilize blood is to absorb it in wheat middlings, rice bran or citrus meal and then spread it out on trays heated from below or dried in the sun. The process may be repeated several times. In this way, the low protein vegetable matter is enriched with protein.

   Blood can also be coagulated by the addition of 1 percent of unslaked or 3 percent of slaked lime and the coagulate then dried. Many minerals and 10 to 15 percent of the dry matter are lost if the coagulate is used rather than the whole blood for production of blood meal. Blood meal made from whole blood will contain more isoleucine, one of the essential amino acids (Göhl, 1975).

   Raw blood can be preserved by the addition of 0.7 percent formic acid or sulphuric acid. Blood treated in this way may be stored for about one week. If 0.5 percent potassium metabisulphite is added to sulphuric acid treated blood, it may be kept for a few months before feeding (Göhl, 1975).

   Fresh blood can be used to feed fish (weekly application of 5 to 10 litres/are), but it is generally mixed with stomach contents or with bran.

   Feeding trials carried out by FAO in the Central African Republic have shown the usefulness of locally produced blood meal in diets for Tilapia nilotica and Clarias lazera. Using a ration composed of 15 percent draff, 20 percent wheat bran, 15 percent rice bran, 30 percent cotton seed cake, 7.75 percent sesame cake, 5 percent fish meal, 5 percent blood meal, 2 percent bone meal and 0.25 percent vitamin mix, with T. nilotica at a stocking density of 20 000 fingerlings/ha, the net production was 6 180 kg/ha/year, with a CR of 1.63 (Miller, 1976). Protein content of the feed was 35.72 percent. A wet combination of cow stomach contents, coarse-ground cotton seed meal and fresh blood in a proportion of 2:1.5:1, yielded a mean net production of 4 309 kg/ha/year with T. nilotica stocked at 20 000 fingerlings/ha. The costs per kg were CFA.F. 37.6 (= U.S.$ 0.16/kg) and a mean feed conversion of 9.4 was achieved in ponds ranging from 31 to 48 ares in area (Miller, 1976).

b. Stomach contents: undigested feeds present in the rumen of cattle at slaughter amount to about 20 to 22 kg for a 240 kg animal starved normally before slaughter and presents a large disposal problem for abattoirs. This material is usually washed into rivers or piled and allowed to decompose. Rumen content contains not only the vitamins present in the feed ingested before slaughter, but is enriched with B vitamins from the rumen flora (Göhl, 1975). The composition of fresh rumen contents is as follows: carbohydrates, 36.2 percent; fats, 1.0 percent; total protein, 11.6 percent; and fibre, 37.8 percent (Miller, 1976).

   Several hundred tons of stomach contents are available annually in Rwanda and this material, not yet utilized, can be collected and used as feed for fish, at almost next to nothing for the farmer. Transport costs however, are Rw.F. 45/ton/km. Stomach contents can also be used to prepare compost, mixed with grasses and farm wastes.

   The rumen contents can be preserved by the addition of sulphuric acid to reach a pH of 3.0, by ensiling together with molasses, or by drying, either in the sun or on trays heated from underneath. If used for feeding, it is important the material is dried immediately. Rumen content silage is palatable to pigs and they can consume up to 0.5 kg per day when they have become accustomed to it. It has also been used mixed with blood in poultry diets (Göhl, 1975).

   In fish farming, stomach contents can be mixed with rice bran, wheat bran, draff, blood, etc.

c. Bone meal: is used as a source of phosphorous and calcium in fish diets. It also provides trace elements. There are different types of bone meal, according to the processing: green bone meal, steamed bone meal, raw bone meal, calcined bone meal, etc. With simple equipment, bones can be processed either into raw bone meal or calcined bone meal; steamed bone meal requires more expensive equipment.

   Calcined bone meal or bone ash is the only recommendable method of utilizing bones. It is made by piling the bones on a metal frame and burning them. Burning sterilizes the bones and deprives them of all organic matter. The charcoal-like bone ash is friable and can easily be pulverized (Göhl, 1975).

   Calcined bone meal is rich in calcium (34 percent Ca of dry matter) and phosphorous (16 percent P of dry matter). (Göhl, 1975.). Bone meal is added up to 5 percent in diets for fish. Bones are in plentiful supply in Rwanda, in the abattoirs and slaughterhouses, generally free of charge.

By-products of rice-milling: threshed rice or paddy, or rough rice, has to be processed to free the paddy from the hull, germ and bran. In many countries this process is carried out in a one-stage mill. The by-product from these mills is a mixture of hulls and bran. In Rwanda, rice bran and rice polishings are available.

a. Rice bran: represents between 2 and 4 percent of the weight of paddy. In 1975, 2 480 tons of paddy were produced in Rwanda, giving about 70 tons of rice bran. Irrigated rice is produced in Rwanda in Kabuyé (10 km from Kigali) and in the prefectures Cyangugu, Butare and Gitarama. Rice is harvested in August/September and February/March. Husking is done in Butare and Kigali in September and March. Rice bran yields a CR of 4.5 and up to 20 percent can be used in fish feeds at a cost of Rw.F. 2 000/ton. For pigs, rice bran should not exceed 30 to 40 percent of the total ration to avoid soft pork. Up to 25 percent can be included in rations for poultry and double that amount has successfully been used in experiments (Göhl, 1975).

b. Rice polishings ('farine basse'): represent about 6 percent of the paddy weight. About 150 tons of rice polishings were available in Rwanda in 1975, at a cost of Rw.F. 2 000/ton. The CR of rice polishings is between 3 and 3.5 and up to 35 percent can be used in fish feeds.

By-products of wheat milling: the wheat grain (or endosperm) is covered with two kinds of fibrous coatings: the coarsest outer one is called bran and under this one a less fibrous aleurone layer (albumen of cereals). During milling the starchy endosperm is separate from the other part of the grain.

Whole wheat after milling yields between 70 and 80 percent white flour and 20 to 30 percent offal consisting of coarse bran, fine bran (aleurone) and germ. The waste consists generally of 2.5 percent of coarse bran, 40 percent of fine bran and 57.5 percent remillings or regrindings ('remoulages').

In the Ruhengeri area 2 300 tons of wheat were produced in 1975, leaving about 460 tons of sharps ('issues de blé'), of which 190 tons were bran and 260 tons, remillings.

a. Wheat bran: is excellent for fish as well as for pigs and poultry. There is no sharp difference between fine bran and coarse bran and these two by-products are generally mixed. The bran fractions contain most of the vitamins and protein of the wheat grain. The protein content of bran is between 14.5 (Hastings, 1973), and 16.9 percent (Göhl, 1975). Up to 35 percent of wheat bran can be used in fish diets, up to 30 percent in pig diets and up to 15 percent in poultry diets. Wheat bran costs Rw.F. 2 000/ton in Ruhengeri.

b. Remillings: are the most common by-product from the flour mills, and up to 45 percent can be used for fattening pigs. Up to 10 percent can be used for poultry and up to 20 percent can be utilized in fish feeds. Remillings contain between 15 and 19 percent protein. The cost per ton in Ruhengeri is Rw.F. 2 000 to 2 500.

Sugar-cane wastes: about 14 000 t sugar-cane was produced in 1975 in the Kabuye area. The by-products of the sugar-cane industry are bagasse, molasses and filter presscake.

a. Bagasse: is the cane waste after it has passed through the crusher where sugar sap is extracted. It represents about 15 percent of the whole sugar-cane plant. An average of 60 percent of the bagasse produced is generally used as fuel in the sugar mills.

   There are two kinds of bagasse fibres: (i) fine, strong and flexible fibres that are suitable for the manufacture of high-grade pulp and paper, and (ii) short fibres or pithy material (bagasse pulp), which are used as animal feed.

   The bagasse production in Rwanda is about 2 100 tons/year. Bagasse or portions of bagasse can be used as roughage for pigs and cattle, or as a carrier for molasses. Bagasse and bagasse pith are good carriers of molasses (four parts bagasse pith and ten parts molasses cane). Bagasse can also be used for compost.

b. Molasses: is a liquid by-product (80 percent dry matter) containing sugar and nonprotein nitrogen; about 2.5 percent of the whole sugar-cane plant. About 350 tons of molasses are presently available in Rwanda. There are different ways in which molasses can be utilized (Göhl, 1975):

   - In dry feeds: molasses have to be absorbed to simplify their transport and handling. Used as a binding product, molasses can replace other more expensive carbohydrates in feeds. Percentages of molasses absorbed by some feed ingredients are as follows: wheat middlings, 19 percent; maize meal, 15 percent; draff, 9 percent. Up to 15 percent of molasses can be fed to pigs and to poultry, and 10 to 15 percent can be included in fish diets. The maximum amount of molasses used is often determined by the absorbability of molasses by the other ingredients in the diet.

     Trials undertaken in the Ivory Coast, with 30 g fingerlings of Tilapia nilotica (stocking density: 1.3/m^2), feeding a mixture of 60 percent molasses and 40 percent rice bran have given the following results: yield: 3 649 kg fish/ha/year; average daily growth increment: 0.78 g/fish/day; CR = 8 (Lazard, 1980).

- In silage making: molasses are quickly fermented and, at a 5 percent level, sometimes added to grass during the ensiling process to preserve the nutrient value and increase palatability.

c. Filter press cake ('tourteaux de filtration'): represents about 2.5 percent of the whole of the sugar-cane (as it stands before harvesting). This product is obtained when the chopped cane is pressed and the sugar is extracted with water. Filter press cake contains many of the impurities of the sugar-cane juice and in organic compounds, mainly calcium sulphate and calcium phosphate. The protein content is between 10 and 15 percent (Göhl, 1975).

   Filter press cake is generally used as a fertilizer for sugar-cane cultivation but it can also be used as a fertilizer in ponds, and to feed fish when mixed with bran or draff.

Maize and by-products: In 1977, 77 166 tons of maize was produced in Rwanda (Morris, 1979).

a. Maize (grain): is a staple food for the population and its possible use as a fish feed is questionable from the socio-economic point of view. The majority of the maize milling capacity is concentrated in centres and the cost of transport to remote areas is high. If used, and to avoid prohibitive costs, maize should be milled at the fish farms using a commercial hammer-mill. Maize (grains) costs Rw.F. 10 000/ton.

b. Maize meal: is available in almost all the prefectures and costs about Rw.F. 17 000/ton. Maize meal levels of 15 to 30 percent are used in fish feeds and 15 to 70 percent in pig and duck feeds. In fish culture the CR of maize meal is between 3.5 to 3.9 percent.

c. Maize bran: is available in some villages, but in small quantities. The optimum level in pig rations is between 20 to 25 percent and about 30 percent in fish diets. Maize bran costs Rw.F. 2 000/ton and the CR is between 4.5 and 5.5 percent.

Groundnuts: between 12 and 14 000 tons (in hulls) were produced in 1975, mainly in the Cyangugu, Kibuye, Gisenyi, Gitarama and Kigali prefectures, as well as in the eastern plateau and eastern savanna. According to Morris (1979), some peanuts, perhaps 50 percent of the supply, are available for oil extraction.

Groundnut press-cake is available in only very small quantities and prices fluctuate from year to year. Shelled weight of peanuts is 70 percent of the weight in the shell. Oil is 50 percent of the shelled weight and the other 50 percent is press-cake (Morris, 1979). The groundnut press-cake content may be 30 to 45 percent in fish feed, 23 to 27 percent in pig feed and 5 to 7 percent in duck feed. Groundnut press-cake contains 53.5 percent protein.

Soybean: the production for 1975 was 2 700 tons, mainly produced for human consumption in the Kibuye (Gitesi), Cyangugu (Bugarema) and Kibungo (Kayonza) prefectures. Soya is mainly grown between 1 400 and 1 800 m altitude.

Soybeans are the richest by far in protein of all the common seeds used in feeds. Soya seeds have a low oil content (maximum 20 percent). Beans are 72 percent of the pod weight. When pressed the oil cake represents about 80 to 82 percent of the seeds and 18 to 20 percent is oil.

Locally-produced soybeans sell at Rw.F. 25 000/ton and imported soya is processed in Kigali. In 1975, 15 300 tons of soybeans were pressed, producing about 10 000 tons of soya oil-cake.

Coffee by-products: the coffee production ('café marchand') in Rwanda was 24 385 tons in 1975. The by-products of coffee are pulp and coffee hulls.

a. Coffee pulp: represents about 26 percent of the whole coffee fruit ('cherry' or 'cerise de café'). The coffee fruit can be processed either by the simple dry method or by the more advanced wet method to liberate the seeds ('coffee beans') from the fleshy wet pulp. Large quantities of coffee pulp (about 10 000 tons/year) are available in Rwanda, free of charge. Coffee pulp can be used as a roughage for cattle and for pigs and also as fish feed, after drying. Wet pulp should be dried immediately (in the sun, as described for brewer's yeast), as it spoils very quickly. Coffee pulp contains between 7 and 9 percent protein (Mongodin, 1977).

Up to 16 percent dehydrated coffee pulp can be included in pig rations (Göhl, 1975), and up to 25 percent in fish diets.

b. Coffee hulls ('parches de café'): are obtained during the decortication process of the coffee beans, and represent 15 percent of the 'café parche'. About 3 000 tons of coffee hulls are available in Rwanda, free of charge. The protein content of coffee hulls is between 6 and 12 percent. Coffee hulls have to be mixed in diets and can be used up to 20 percent. If used as a single feed, CR of coffee hulls is 40 (Lazard, 1980).

Cassava waste: In 1977, 414 326 tons of cassava were produced in Rwanda, at a value (market price) of Rw.F. 8 000/ton. The average consumption of manioc (Cyangugu Prefecture) is about 113.2 kg/per caput/year (Morris, 1979).

Cassava tubers or roots have a poor protein content (about 3.6 percent), but protein content in the peel and in the external parts of the root is relatively high. By retting cassava, a necessary practice to liberate the hydrocyanic acid from the tubers, some of the nutrients are dissolved in the water.

Peeled cassava ('manioc pelé'), after retting, represents about 68 percent of the fresh tubers. Offals are about 32 percent of the fresh roots. 'Cossettes' are 33 percent and flour, 31 percent of the fresh root weight (Morris, 1979).

Hydrocyanic acid can cause fish mortality if too much cassava is retted in a small water area. According to FAO trials set up in the Central African Republic (CTFT, 1972), the fish mortality (Tilapia nilotica) is as follows:

- peelings of 10 kg raw cassava tubers in 100 litres of water: total fish mortality occurs after 24 hours (density not stated);
- peelings of 5 kg raw cassava tubers in 100 litres of water: high mortality occurs after 48 hours;
- peelings of 1 and 2 kg raw cassava tubers in 100 litres of water: no mortality occurs.

Trials on cassava retting in fish ponds were undertaken in Gabon with the following results (CTFT, 1972):

Retting			Yield (Tilapia nilotica)		
10 kg raw cassava tubers per are/week			2 400 kg fish per ha/year		
100 kg	"	"	4 280	"	"
200 kg	"	"	4 000	"	"

One should note that retting large quantities of cassava tubers to obtain only a few kilogrammes of fish can still be economical. Since retting bitter cassava is absolutely necessary before consumption, it is generally done in brooks and rivers instead of ponds.

As cassava is a staple food in almost the whole country, retting cassava tubers is carried out in many villages. It can also be carried out in fish ponds, using approximately 100 kg tubers per are/week. With this method, the average yield can reach between 3 000 and 4 000 kg fish per ha/year.

Household scraps: are very nutritious, but are not always collected and utilized as fish feeds. Pot scrapings, vegetable wastes and fruits (Mango, papaya, etc.), cassava offal, rice, maize, etc., are available daily in all families and can be collected as fish feed. Depending upon the composition of the scraps, CR is between 8 and 20.

Wastes from markets, restaurants, hospital and boarding-schools: are now used as fish feed at the Kigembe fish farm. They are collected, free of charge, mostly in Butare, and transported (19 km) to the station.

The cost of these ingredients delivered at Kigembe is about Rw.F. 0.85/kg. The CR of these wastes is between 6 and 25 (6 to 25 kg wastes, depending on their nature and average composition, needed to produce 1 kg fish).

Wastes from markets, because of their nature (leaves, stalks, bunches of bananas, spoiled fruits, sweepings, etc.), are sometimes better for composting than for direct feeding in ponds.

ANNEX 8
Feed Formulae for Fish in Rwanda

A. Diets with 25% Protein (kg)

Ingredients	Percentage Compositions of Various Compounded Feeds (Chow, 1980)													
Groundnut cake	48	30	30	80	-	20	20	-	-	-	-	-	-	-
Rice bran	50	40	40	18.5	80	60.5	60.5	-	-	-	-	-	-	-
Limestone	1.5	1.5	1.5	1	1	1	1	-	-	-	-	-	-	-
Vitamin premix[1]	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Brewery waste, dry	-	28	-	-	-	9	-	-	-	-	9	-	20	-
Brewery waste, wet	-	-	80	-	-	-	37	-	-	-	-	36	-	81
Blood, fresh	-	-	-	-	83	-	40	-	-	86	-	40	-	-
Blood meal	-	-	-	-	-	9	-	-	19	-	9	-	-	-
Soybean cake	-	-	-	-	-	-	-	46	-	-	20	20	38	38
Maize bran	-	-	-	-	-	-	-	52	79	79	60	60	40	40
Bone meal	-	-	-	-	-	-	-	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Groundnut cake	65	47.5	47.5	18	18	37.5	37.5	-	-	-	-	-	-	-
Rice bran	33	22.5	22.5	58	58	43	43	-	-	-	-	-	-	-
Limestone	1.5	1.5	1.5	1.5	1.5	1	1	-	-	-	-	-	-	-
Vitamin premix[1]	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Brewery waste, dry	-	28	-	-	-	9	-	-	-	-	9	-	20	-
Brewery waste, wet	-	-	80	-	-	-	37	-	-	-	-	36	-	81
Blood, fresh	-	-	-	-	81	-	40	-	-	86	-	40	-	-
Blood meal	-	-	-	18	-	9	-	-	19	-	9	-	-	-
Soybean cake	-	-	-	-	-	-	-	62	17	17	36	36	54	54
Maize bran	-	-	-	-	-	-	-	36	62	62	44	44	24	24
Bone meal	-	-	-	-	-	-	-	1.5	1.5	1.5	1.5	1.5	1.5	1.5

[1] It is doubtful whether the use of 'premix', a prefabricated mixture of vitamins, is feasible for rural fish farmers. Its use should, therefore, be considered optional.

Source: K.W. Chow (pers.comm., 1980)

ANNEX 9
Fertilizers

Chemical fertilizers

When using chemical (inorganic) fertilizers, such as superphosphate, triple superphosphate, ammonium and urea, it is recommended to apply these fertilizers every two weeks (Miller, 1976).

While awaiting the results of new trials to be undertaken at the Kigembe Centre, the following rates of application of inorganic fertilizers are recommended:

- Superphosphate (18% p_2O_5): 0.300–0.400 kg/are, fortnightly
- Triple superphosphate (45% P_2O_5): 0.150 kg/are, fortnightly
- Ammonium sulphate (20% N): 0.200–0.300 kg/are, fortnightly
- Urea (46% N): 0.100–0.200 kg/are, fortnightly

Using only superphosphate and ammonium sulphate at the above rates, the cost of fertilization, including application, will be about Rw.F. 980 per are/year or Rw.F. 98 000 per ha/year.

Calcareous fertilizers

Liming is indispensable when the pH of the water is too low (below 6.0–6.5). The best water for fish cultivation is that with a pH between 7.0 and 8.0. As already explained, marshy and peaty water are too acid.

The nitrification of ammonium compounds into nitrites and nitrates demands the presence of sufficient quantities of lime.

The principal fertilizers containing lime useful for liming ponds are: powdered limestone, marl, quicklime, caustic lime and calcium cyanamide. At present, only powdered limestone is available at Rubona and costs Rw.F. 16/kg.

For the purpose of controlling the acidity of the water, one can use powdered limestone at the following rates of application:

- in new ponds with acid water (pH between 4.0 and 6.5): 15–20 kg/are (1 500–2 000 kg/ha) on the bottom when the pond is dry. After spreading out, powdered limestone has to be lightly worked in and the pond can be filled. The cost of such an application is estimated to be Rw.F. 240–300 per application and per are.
- other ponds: monthly application of 1.5 to 2 kg/are, at a cost of Rw.F. 288–384 per are/year (Rw.F. 28 800–38 400 per ha/year).

Manures

Relatively high production can be obtained combining organic fertilization of the ponds and supplying supplemental feed. The following is a brief summary of the availability and application of various manures:

- Cow manure: is relatively easy to obtain in the country. One cow produces annually about 16 tons of manure, which can be used to fertilize a 1-ha pond at a rate of 300 kg manure/ha/week (or 3 kg/are/week).
- Horse manure: may also be used, but is often not available in large quantities. Recommended application rate: 20 to 30 kg/are, monthly.

- Pig manure: raising of pigs in pens and beside or over fish ponds, permits continual organic fertilization of the ponds and appears to work very well with Tilapia nilotica as well as other tilapia species, and common carp.

- Poultry manure: in Central East Africa, Maar et al., (1966) recommended the use of poultry manures at a weekly application rate of 120–220 kg/ha (6 240–11 440 kg/ha/year). The manure produced in a year by 100 chickens is about 1 900 kg. In tilapia culture (T. nilotica, two fingerlings/m^2) with artificial feeding, the application of poultry manure at an initial rate of 2 500 kg/ha, followed by monthly applications of 1 000 kg/ha (12 000 kg/ha/year) gives an additional production of about 1.5 tons tilapia/ha/year. This manure can only be used if there are poultry farms near the ponds.

The composition of some manures is presented in Table A.

Table A

Composition of Various Manures

	N (%)	P_2O_5 (%)	K_2O (%)	CaO (%)
Cow manure	0.3	0.15	0.10	0.45
Horse manure	0.45	0.35	0.35	0.15
Pig manure	0.6	0.40	0.25	0.10
Poultry manure	1.7	1.7	0.85	2.40

Compost

When manures are not steadily available one can utilize compost for the fertilization of the ponds, as is practised in rural ponds in the Central African Republic. Natural productivity in ponds in Central Africa is around 200 kg fish per ha/year. In monoculture of T. nilotica stocked with 2 fingerlings/m^2, the average production from ponds where compost is used is 1 500 kg fish/ha/year. The compost is stacked underwater in a 1 m^3 pile in the corner of the filled pond, with weekly doses of 9–10 kg organic matter (grasses, spoiled fruits, wastes from soaking cassava and some cattle or chicken manure) then being added to the pile. To collect, transport and pile the organic matter for composting a 100 m^2 pond, the farmer may spend an average of 28 hours a year.

With aerobic prepared compost, production can reach 3 000 kg of fish/ha/year, with an application rate of 20–30 tons compost per ha/year (C.T.F.T., 1972).

The fertility of compost depends broadly on the mineral content of the used grasses and organic matters to prepare the compost, and the method of preparation (aerobic or anaerobic methods). Organic matters, stacked underwater in piles scattered around the edges of filled ponds, generally produce relatively low fertility, because decomposition is anaerobic and slow. Decomposition (rotting) of organic matters in compost piles (aerobic conditions) is more rapid and more complete, giving a richer fertilizer than the anaerobic prepared compost.

Preparation of compost under aerobic conditions is easy. A trench of about 1.20 m wide and 0.50 m deep is dug. The length of the trench depends on the quantity of compost needed. To obtain good fermentation, it is necessary to apply alternatively a layer of fresh fodder, rich in nitrogen and then a layer of dried organic matter. Fresh fodder can be composed of all kinds of organic wastes (spoiled fruits, vegetable wastes, garbage, household refuse, sweepings, etc.), but no woody material. The dried organic matter is made from grass and is arranged in piles of 20–30 cm thick layers in the trench to a height of 1.50 m. The layers should be compressed slightly and, if available, some manure or ash (rich in minerals) can be added between the layers. Coarse materials should be chopped before piling.

Between 5 and 7 tons of organic matter is needed to prepare a 9 m^3 compost pile. One of the best composts is prepared with a mixture of green fodder and household refuse, garbage from towns and night soil. When the pile is made up, water has to be sprayed on it to initiate the fermentation process (about 30 litres water/day is needed for a 9 m^3 pile, except during the rainy season). Approximately one month after completing the pile it is necessary to mix and turn over the compost and then place it in another trench. Only during the dry season should watering be continued. Decomposition is complete about two months after the turning over of the pile. Thus, compost can be prepared every three months, giving each time about 2 800 kg compost for a 9 m^3 pile. The cost of preparing such compost is estimated at Rw.F. 400/ton. At doses of 20–30 tons/ha/year, composting of ponds costs between Rw.F. 8 000 and 12 000/ha/year.

The best fodders are made from leguminous plants rich in protein and minerals, such as aerial portions of peanut (Arachis hypogaea), Calapogonium muconoïdes, Crotolaria mucronata, Dolichos lablab, Soya, Leucaena glauca, Pueraria thunbergiana (Kudzu), Mucuna utilis (Velvet bean), Stylosantes sp., Vicia sativa and Voandzeia subterranea.

Grass has to be cut from natural (or artificial) grasslands around the fish farm if the cuttings from grasses on the dikes of the ponds are not sufficient to make up the compost piles. Common grasses, such as Brachiaria ruziziensis, Chloris gayana, Cynodon dactylon, Hypparrhenia rufa, Imperata cylindrica, Loudetia arundinacea, Paspalum spp., Pennisetum glaucum and P. purpuream are very suitable for making compost. Also, aquatic grasses growing along rivers, in swamps and in ponds are suitable, such as Echinochloa pyramidalis, E. staginina and Leersia hexandra, containing between 5.8 and 11 percent crude protein (CP) and between 8.6 and 16 percent ash (Göhl, 1975).

Artificial manure

If only grasses and a few organic matters are available, artificial manure can be used to fertilize the ponds. The preparation of artificial manure is roughly the same as that for compost, but chemical nitrogen fertilizer (generally urea) is added to the grasses and organic matter during the preparation of the manure. Artificial manure of good quality is as rich as farmyard manure and one ton contains approximately 150–180 kg organic matter, 4.5–5.4 kg nitrogen, 2.0–2.5 kg phosphoric acid, 6–7 kg potassium and 4–5 kg of calcium, depending on the mineral content of the grasses and organic matter used to prepare the artificial manure, the fertilizers used and the methods of preparation.

The following method of preparation of artificial manure was suggested during 1972–73 at the Agriculture Section of the Institut Technique Agricole du Burundi (ITAB) (De Valck, pers.comm., 1978):

In a trench of 4 × 4 m and 1.75 m deep (28 m^3) fresh chopped fodder is placed in 20–30 cm thick, not compressed, layers. Between each layer urea should be sprayed (46 percent N). To fill the 28 m^3 trench, about 17 tons of green organic matter is needed, together with 8 kg of urea. The pit, after filling, has to be covered by earth and water and sprayed (about 60–70 litres/day), except during the rainy season. After one month the trench has to be emptied for aeration of the manure. The manure has to be turned over and replaced in the same pit for one more month. Generally after two months, 9 tons of manure is ready for use. Application rate of artificial manure in ponds is between 20 and 30 tons/ha/year at a cost of Rw.F. 7 500–11 300/ha/year.