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Sierra Leone aquaculture assessment with special reference to Tonkolili and Bombali districts

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WorldFish

Sierra Leone aquaculture assessment with special reference to Tonkolili and Bombali districts

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Contents

Executive summary

Current finfish aquaculture in earthen fishponds was introduced in Sierra Leone in 1978 by the then Ministry of Agriculture and Natural Resources (MANR), under which the Department of Fisheries and Aquaculture was placed. Various studies have recorded up to 2590 fishponds, mostly in Tonkolili and Bo districts, but a good number of these were not in active production at the time of this study. Over 200 fish farmers were interviewed during this assessment, and they advanced various reasons for abandoning their fishponds after investing so much labor and time to construct them.

- Inputs for fish farming in ponds are not available locally in Sierra Leone.
- Natural predators eat the fish in the ponds.
- Fishpond culture has so far proven expensive to initiate and not financially viable to run.
- The fish farmers have very little technical know-how to grow fish.
- Cultured fish exhibited poor growth because of a lack of feed and quality seed.
- Fish farming is labor intensive and time consuming.
- Poachers steal fish from the ponds.
- Floods sometimes flush fish out of the ponds because of heavy rainfall as well as poor siting and construction.
- The mortality rate for fish is high during rearing and transportation.
- Water sources for ponds are not perennial (ponds dry up in the dry season), which is a result of poor site selection.

Fish farming in ponds will never succeed under the prevailing circumstances and conditions in many areas in Sierra Leone. This assessment therefore set out to investigate why fish farming has spread in Tonkolili District yet been poorly adopted in neighboring Bombali District. The purpose was to analyze what was working in Tonkolili but not in Bombali and then extrapolate this beyond Tonkolili.

The methodologies used included a review of documented literature and a comprehensive documentation of all fishponds in Bombali and Tonkolili districts, using a geographic positioning system (GPS) and a digital camera, by physically visiting the pond sites and assessing various factors, including status, ownership, cultured species and the date each fish farm was established.

This documentation was followed by a rapid rural appraisal (RRA) or participatory rural appraisal (PRA) using transect walks, focus group discussions (FGDs), key informant interviews (KIIs), ranking exercises and consultative workshops. In the workshops, specifically, strength, weaknesses, opportunities and threats (SWOT) were analyzed, and factors affecting aquaculture development were identified, ranked and assigned weights according to their relative importance.

The RRAs investigated the following:

- Where and why are fishponds sustained and successful?
- Where and why are fishponds a total failure and unsustainable?
- What are the reported factors responsible for the success and failure of fishponds in the districts of interest from the baseline surveys and comprehensive records of fishponds in Tonkolili and Bombali districts?
- How can recorded failures in fishponds be corrected and successes be improved?

The following are the key findings and recommendations of this assessment:

- Despite a culture and tradition of eating fish, Sierra Leoneans are only using free-range methods for domesticating animals or livestock, which are left to fend for themselves. Livestock farmers normally mark their animals so that they do not lose them. The animals roam about a wide area in search of food, mostly grasses, which are abundant during the rainy season. This method is not suitable for domesticating or farming fish, particularly in ponds, if the enterprise is for profit. Fish are limited by the size of the ponds and the amount of food available in this natural ecosystem. Rural crop farmers, particularly those growing paddy rice and vegetables in inland valley swamps (IVSs), are quick to agree to construct fishponds, but thereafter they do not have time to care for or feed the fish they have stocked. They expect that the fish would be able to take care of themselves and that there would always be fish in the pond once they begin reproducing, so farmers only return to their fishponds to harvest (selective/partial).

- The rural farmers who have adopted fish farming so far lack the necessary capital to do semi-intensive fishpond culture. The emphasis should be to attract private sector investment, of different scales, into the production system so that some of the young people employed in such businesses can learn practically that fish farming can be a profitable business.
- Land tenure reforms are a prerequisite to attract private sector investment in fish farming. Many of the people who could invest in fish farming are not crop farmers, but they are more entrepreneurial and have the required capital. However, they do not have secure access to suitable land, and those who do are not willing or do not have the right to sell it because it is family land, which is believed to be property of the living and the dead.
- Most of farmers who have fishponds do not recognize the monetary value of the fish they harvest and consume in their households. For them, if fish is consumed by the family, it is not considered money, so they rank fish farming relatively low, particularly for men in the rural areas, who are only responsible for providing the rice cooked by their wives daily. Fish and other ingredients that go with the rice are the absolute responsibility of the wives.
- Only a few farmers have the technical knowledge required to construct and manage fishponds sustainably and profitably. They said they were trained in Tonkolili District by the Peace Corps in the 1980s and have since adopted the technology and continued to use it.
- The development approaches of some NGOs and donors, such as CARE International, the Catholic Agency for Overseas Development in Sierra Leone, CONCERN Worldwide, the Food and Agriculture Organization of the United Nations (FAO) and World Vision, in supporting aquaculture have targeted poor rural communities. Yet the support programs have all been short term. The farmers were either encouraged to rehabilitate existing fishponds abandoned during the civil war from 1991 to 2001 or to construct new ones. After the support ended, the farmers were left on their own with no knowledge or technology transfer to enable them to manage the ponds sustainably and profitably on their own. Longer-term support is required (a minimum of 5 years) for farmers to fully understand and appreciate the production technology and be able to sustain production after support ends.
- The government hatchery in Makali and the fish experimental station in Bo are improperly managed, so they are not effectively delivering on their objectives of supplying quality fish seed. The fisheries and aquaculture technicians and assistants in these stations do not have the capacity, training and logistical support needed to assist farmers with technical knowledge and extension services.
- There is currently no specialized commercial private sector fish feed manufacturing establishment in the country, and private sector entities are not importing fish feed. Njala University has a project, under which the Department of Aquaculture and Fisheries Management hopes to formulate fish feed from local ingredients and eventually get the formula commercialized.
- The only fish farming technology promoted in Sierra Leone so far has been fishpond culture. The ponds are often sited far away from homesteads, so theft and natural predation can become serious problems, which make fish farming unattractive. Collapsible plastic tanks in the backyards of many mid- to higher income level earners in urban centers could potentially be more attractive (e.g. as in Nigeria with catfish), sustainable and profitable, since the target investors would be able to buy inputs and pay for training and technical advice. This has not happened, however, because the efforts of both the Government of Sierra Leone (GoSL) and NGOs have targeted the poorest of the poor in their development support at a one-for-all level approach, while ignoring mid- to higher income entrepreneurs.
- The presence of the government hatchery and technicians in Tonkolili since the 1970s, the Peace Corps volunteers in the district in the 1980s and the experimental fish station in Bo in the late 1970s to the early 1980s are the primary factors responsible for the prevalence of the relatively large number of fishponds in Tonkolili and Bo districts. If the hatchery and experimental stations or practical demonstration farms were maintained properly, the aquaculture technicians given the required training and logistical support to provide extension services, quality fish feed made more available and these facilities replicated in some other districts, then there could be a wider adoption of fish farming in other parts of the country. However, at the time of this assessment, even the one government hatchery in the country was not functioning. It is likely that the GoSL has not put much importance into fish farming because there is still abundant fish coming from the marine capture fisheries.

- A properly managed hatchery and a fish feed production facility would be necessary to attract private sector investment into aquaculture. This must be a priority for the government and its development partners and donors to lure the private sector into fish seed and feed production. For sustainable operations, the GoSL should divest the hatchery to the private sector and the experimental station to Njala University for research and development.
- The University of Sierra Leone and Njala University should develop mid-level labor by training the technicians, engineers and hatchery specialists at certificate and diploma levels alongside theoretical degree graduates in the sciences and humanities, because the degree graduates only look forward to landing office jobs after graduation and not applying practical knowledge on fish farms.
- Development partners and NGOs should rethink their support policies with a view to targeting individual farmers and households instead of whole village communities. These should include nonfarmers, such as entrepreneurs in urban and peri-urban areas. Support should include practical training and technology transfer and advice on access to farm inputs and markets for the fish produced.
- Donors, NGOs and developmental organizations should (a) provide assistance for institutional capacity building in research management as well as scientific skills in critical disciplines, (b) institutionalize national training programs and support the upgrading of local educational programs, (c) promote and strengthen trust and cooperation among the players in the value chain, (d) facilitate access to rural financial services tailored to the specific needs of farmers, (e) encourage the formation of farmer-based organizations (FBOs) to share knowledge, skills and market intelligence information, and (e) strengthen knowledge and skills not only in changing the attitudes and behaviors of farmers to become primary producers but also to develop entrepreneurship skills to become secondary producers, such as successful processors and traders.
- NGOs and development partners should facilitate the decentralization of the fish seed supply and enhance it in other the districts where the potential for aquaculture development exists.
- Many of the areas where fishponds have been successful and sustainable are suitable for pond culture of fish, while other areas where ponds have not been sustained are either moderately suitable or unsuitable. Therefore, farmers should be advised or trained on the criteria for selecting suitable sites for pond construction, not just anywhere where they can find water.

Introduction

Background and objectives

"Modern" inland finfish farming in Sierra Leone started in 1976 with the establishment of a government fish breeding station at Makali in Tonkolili District. Then in 1988, the Bo/Pujehun Rural Development Project set up a government aquaculture experimental station in Bo. The fishponds that farmers constructed under that project were all stocked with the Nile tilapia (*Oreocromis niloticus*) from Ivory Coast. Annual production figures ranged between 600 and 4000 kg/ha with an average of 2500 kg/ha. The fish produced from these fishponds were consumed in rural areas, particularly in noncoastal communities.

Apart from these two major government interventions in aquaculture introductions and development, other partners such as FAO as well as national and international NGOs have supported some form of aquaculture development and production at various stages and levels in Sierra Leone. Some development partners and NGOs have supported studies, such as the African, Caribbean and Pacific (ACP) Fish II Project funded by the European Union (EU), while others have provided financial and technical support, like the FAO Technical Cooperation Project (TCP) (both past and present). Many NGOs intervened in agriculture and aquaculture production and development after the country's decade-long civil war to help rural farmers resettle in their communities after being displaced. One strategy that NGOs have used since the war has been to help internally displaced rural farmers rehabilitate their fishponds or construct new ones on their return in exchange for food, farm tools or, in a few cases, for cash.

The objectives of these interventions were to support rural livelihoods in diversification, income generation, youth employment, nutrition and food security following the civil war. After many such interventions, principally after 2002, the Ministry of Fisheries and Marine Resources (MFMR) commissioned the following four aquaculture baseline studies:

1. the 2005 Aquaculture Baseline Studies funded under the African Development Bank-financed Artisanal Fisheries Development Project (ADB-AfDEP)
2. the 2012 Aquaculture Baseline Studies funded by the New Partnership for Africa's Development's (NEPAD) Partnership for African Fisheries (PAF)
3. the 2013 Comprehensive Aquaculture Baseline Studies funded by the ACP Fish II project.
4. the 2015 Aquaculture Baseline Studies funded by FAO's TCP.

WorldFish commissioned this study using the ACP Fish II Baseline Studies, which reported a total of 2594 fishponds in Sierra Leone (as recorded by MFMR officials in 2009), of which 2164 were in Tonkolili District alone (Table 1), as reference point. There are three questions that this assessment attempts to answer.

1. Why are almost all of the fishponds in Sierra Leone concentrated in Tonkolili, and how are they distributed within the district?
2. Are the fishponds located in suitable areas for pond aquaculture development?
3. How do the findings of this study complement or fit into FAO's study and other earlier assessments, including the aquaculture development site suitability models developed by Sankoh (2009).
4. The current study therefore aims to consolidate the most recent FAO study and map out pond distribution in Tonkolili, the most popular aquaculture development district in Sierra Leone, while also trying to make sense of this distribution. It also tries to update existing GIS models for aquaculture site suitability, particularly Tonkolili, with a view to identifying the opportunities and challenges of developing aquaculture in the country (refer to Table 1).

Aquaculture sector overview

Research and trials on oysters

Oyster culture research and trials in the country began in 1964 in Bonthe (Southern Sierra Leone) with mangrove and mud oysters (Anon 1964), but work at the station was discontinued because of poor site selection (Anon 1965). In 1973, an oyster culture project jointly sponsored by the GoSL and the International Development Research Centre (IDRC) of Canada was implemented (Kamara and McNeill 1976).

Mangrove, mud and rock oysters were cultured on beaches, trays and rafts. Suspended raft cultures were promising followed by subtidal rack culture. The two culture methods were practised on an experimental basis, and the growth rates of the oysters were significant. In 7 months, the oysters reached market sizes of 70 mm in diameter, each of which yielded 5–6 g of meat (Kamara and McNeill 1976). Environmental conditions supported year-round oyster production in the experimental stations. However, commercialization of the project was not achieved because oysters were abundant in the wild in Sierra Leone and were not expensive in local markets. The European market for oysters was attractive at the time, but the oysters had to be delivered live and needed to meet European safety and quality standards. These conditions could not be met at the time, so the project ended at the experimental stage and folded after the IDRC funding ended in 1983.

In the late 1980s, the Sierra Fishing Company undertook feasibility studies for shrimp culture, and the company still maintains an interest to try shrimp culture on a commercial basis.

Earthen fishponds

Inland finfish farming began in 1976 with the establishment of a fish breeding station at Makali and later followed in 1988 by the Bo/Pujehun Rural Development Project, which set up an aquaculture experimental station in Bo (Bangura and Sheriff 1991; Bangura and Cole 1987). However, finfish farming accounts for only about 40 t of annual fish production in Sierra Leone. The fish produced from aquaculture are consumed by the rural population and are particularly important for noncoastal areas. FAO's 2002 annual statistical bulletin estimated national annual production at 30 t, which was made up entirely of Nile tilapia, with an estimated total value of USD 45,000 based on a cost of USD 1.5/kg (Hecht 2006).

Current trends

After the government's initial interventions, many donor agencies and NGOs also supported various projects in agriculture and aquaculture. By the late 1980s, the techniques for simple fish culture in ponds were fairly established, and in 1990 there were 453 fishponds owned by different farmers in rural Sierra Leone (ASMPlan 1992).

The development policy measures for inland fisheries and aquaculture were initially aimed at achieving self-sufficiency in fish production for the rural populations bordering water bodies and those around the IVSs and floodplains. These measures were seen as significant to provide essential fish protein to supplement catches from marine fisheries. The emphasis on food self-sufficiency for rural farmers was probably because for a long

District	Number of ponds	Average size of pond	Percentage of active ponds	Number of fishponds in active production	Area of production (ha)	Production (t/year)
Bo	277	304	52	143	4.35	6.53
Bombalie	28	479	36	10	0.49	0.73
Bonthe	3	324	75	2	0.07	0.11
Kailahun	20	330	71	14	0.47	0.70
Kambia	12	195	0	0	0.00	0.00
Kenema	5	384	40	2	0.08	0.12
Koinadugu	7	763	100	7	0.53	0.80
Kono	25	347	8	2	0.07	0.11
Moyamba	4	233	0	0	0.00	0.00
Port Loko	12	560	57	7	0.38	0.58
Pujehun	11	196	88	10	0.19	0.28
Tonkolili	2,164	344	73	1,590	54.76	82.13
Western Area	25	295	53	13	0.39	0.58
Total	**2593**	**365.7 m²**	**50.2%**	**1,800**	**61.78**	**92.67**

Table 1. Results of the 2009 aquaculture baseline survey (Dabo et al. 2009).

time what is now the MFMR used to be a department under the MANR, so fish farmers were likely considered the same as crop farmers. Even though the MFMR is no longer a department under the agriculture ministry, fish farming is still regarded as animal husbandry under agriculture, so the focus has remained to encourage crop farmers to grow rice and fish or diversify their crop production options for either a balanced diet or additional household incomes.

As of 2016, the various types of aquaculture productions systems used in Sierra Leone include earthen ponds, integrated fish and rice farming, fish culture in concrete tanks, and artificial lakes created in mined out areas. The integration of fish and rice farming has great potential, particularly in riverine grasslands, *bolilands* and IVSs (FAO/ICLARM/IIRR 1998), and such considerations highlight the proven profitability of fish farming in many other parts of sub-Saharan Africa (FAO 2008; Frankic and Hershner 2003; Hecht 2006).

The pace of aquaculture development in Sierra Leone has been noticeably slow since its inception in the 1970s. Fish culture is still largely practiced at the subsistence level or as a backyard activity. The prospects for commercial aquaculture will remain a distant dream until significant strides are taken toward full commercialization. Its potential for food security, employment and household income generation still remains untapped.

Through the MFMR, the government has expressed a strong desire to develop aquaculture as a means of providing affordable fish protein to the poor and the fast growing rural population (GoSL 2008). In rural settlements located along rivers and in wetlands, local freshwater fish provides a major source of animal protein. In these areas, village women and children use traditional fishing gear, such as scoop nets, fencing techniques, brush parks, gillnets and traps, to capture fish from these water bodies. In this way, families benefit from the seasonal abundance of these stocks and enhance the family's income (GoSL 2013).

Methodology

Desk review

Aquaculture baseline reports (particularly the most recent one commissioned by FAO), development project reports, policies and legal frameworks from documents of the MFMR and the Ministry of Agriculture, Forestry and Food Security (MAFFS) were reviewed and analyzed for consistency with aquaculture development aspirations and objectives. Published and unpublished works on aquaculture development in Sierra Leone were also reviewed.

Geographical coverage and basic facts about study areas

The baseline study commissioned by FAO covered four districts, namely Kenema, Kono, Tonkolili, Bo and Bombali, while this aquaculture assessment study was confined to Tonkolili and Bombali districts. A geographical and demographic summary of the districts covered both by the baseline survey and this assessment is found in Table 2. A summary of vital facts is presented in the sections below.

Kenema District

Kenema City, which is the third-largest city in Sierra Leone, is the capital of Kenema District. Other major towns in the district include Tongo, Blama and Yomboma. Kenema is made up of 16 chiefdoms and covers an area of 6053 km^2. It is the most populous district in Eastern Province, with a population of 545,327. The population is ethnically diverse, the largest being the Mende people, and is split between Muslims and Christians. Kenema District has a mixed economy, made up of gold and diamond mining as well as agricultural production of coffee, cacao and rice.

Kono District

Kono is a diamond-rich district in Eastern Province. Its capital and largest city is Koidu Town. Other major towns in the district include Motema, Yengema, Tombodu, Jaiama Nimikor and Sewafe. The district has a population of 352,328 and is divided into 14 chiefdoms. It is one of the most ethnically diverse districts in Sierra Leone and is split between Muslims and Christians. Kono District is the largest diamond producer in Sierra Leone. Other important economic activities include gold mining and agricultural production of rice, coffee and cacao.

Bombali District

Bombali is located in Northern Province. Its capital, Makeni, is the largest city in the north. Other major towns in the district include Kamakwie, Kamabai, Karina and Binkolo. Bombali is the second-largest district in Sierra Leone in geographical area, after Koinadugu, and the second-most populous district in the north, after Port Loko, at 434,319. It is made up of 13 chiefdoms and occupies a total area of 7985 km^2. It borders the Republic of Guinea to the north, Port Loko and Kambia districts to the west, Tonkolili District to the south and Koinadugu District to the east.

Tonkolili District

The capital and largest city in Tonkolili is Magburaka. Other major towns include Mabonto, Bumbuna, Makali, Masingbi, Yele, Bendugu, Mile 91, Bumbuna, Yonibana and Matotoka. Tonkolili has a population of 531,435. It is made up of 11 chiefdoms and occupies a total area of 7003 km^2. Tonkolili has significant potential for an extractive economy, specifically the mining of iron ore, bauxite gold and to a lesser extent diamonds. The district holds the biggest iron ore deposit in Africa and the third-largest in the world. It also has huge potential for agriculture (mainly cocoa production), sugar and rubber, hydroelectricity and wildlife.

Bo District

Bo is the second-most populous district in Sierra Leone, and its capital, Bo, is the second-largest city in the country. Other major towns include Baoma, Bumpeh, Serabu, Sumbuya, Baiima and Yele. The district is subdivided into 15 chiefdoms with a population of 561,524 and a total area of 5473.6 km^2. Trading, gold

Province	District Name	Capital City	Area (km^2)	Population (2010 estimates)
Northern	Tonkolili	Magboraka	7,003	347,197
Northern	Bombali	Makeni	7,895	408,390
Eastern	Kenema	Kenema	6,053	497,948
Eastern	Kono	Sefadu	5,641	335,401
Southern	Bo	Bo	5,219	463,668

Table 2. A geographical and demographic summary of the districts in the study.

and diamond mining are major economic activities in the district, as well as agricultural production of rice, coffee, cacao and oil palm.

Survey design/methodology

Fieldwork

Sampled communities

Bombali and Tonkolili districts were sampled for this assessment (see Annex 1 for survey instrument details), and the data generated under the FAO Aquaculture Baseline Survey in Bo, Kenema, Kono and Tonkolili were reviewed for a more representative sample framework.

In the first month of fieldwork, a team of eight research assistants and a lead consultant documented the GPS coordinates of all existing ponds in Tonkolili and Bombali districts together with pond characteristics (Annex 1). The PRA team was made up of extension agents from MAFFS and the MFMR. Sometimes, NGO officials, teachers from the village schools and youth leaders were also drafted into the team and exercises as and when they were available and willing to participate. In addition to the documentation of GPS coordinates and ponds characteristics, 3 weeks of PRAs collected relevant information and data required for the development and update of the aquaculture site suitability models for Tonkolili District. PRA tools used in the assessment included transect walks, FGDs, KIIS, ranking exercises and a SWOT analysis.

Transect walks

Transect walks are a highly participatory and relaxed technique that enhance local knowledge and can be used in low-literacy communities like Tonkolili and Bombali districts. They are observational walks, during which attention is specifically paid to people, buildings, activities, resources, environmental features, etc. (Barton 1997). Observational walks may be taken in a meandering way, following a particular feature of the landscape or the interests of the observer(s). The walks can also be in a straight line, cutting across the terrain in a specific way, such as a compass direction. Walks of this kind help verify information provided on maps, both through direct observation and in discussions with people met along the way (Barton 1997). There are two broad categories of transect walks.

1. Social transects focus on housing types, infrastructure and amenities, religious and cultural features and behaviors, economic activities, skills and occupations.
2. Land-use transects focus on environmental and agricultural features, such as water bodies, cultivated land, forests, soil and crops, slopes and elevations.

The transect walks in this assessment recorded both social and land-use information using a GPS and digital cameras. Before setting off for the walks, PRA team members were given basic training and decisions were made as to what issues to focus on and what information needed to be collected and why.

During the walks, team members took digital photos and notes on relevant features and recorded the GPS positions of such features like ponds, markets centers and agri-business centers (ABCs). Problems and opportunities were discussed with local people and clarification sought. After the walks on each day, notes taken during the walks were discussed.

Focus group discussions

Focus groups are semi-structured discussions with a small number of people, such as fish farmers in a village, sharing common interests. Participants of FGDs were people who were knowledgable and interested in the topics discussed (Chambers 1992; Theis and Grady 1991). Five FGDs with six to 10 participants were held in Tonkolili and two groups in Bombali. Each discussion lasted for approximately 1 hour. A list of topics was prepared and group members were asked to give their own views and perceptions in turns. The FGDs also included land and water resources access and tenure rights, fish consumption preferences and prices, livelihoods options and gender roles in farming activities.

Male and female groups were held separately and then mixed, because women spoke more freely when the men were not around. Village teachers and youth leaders were sometimes requested to act as group facilitators because they understood the local language. (Languages mostly spoken are Temne in Tonkolili and Limba and Temne in Bombali, but almost all inhabitants spoke Krio, which is widely spoken in all districts in Sierra Leone.) One or two of the RRA team members acted as rapporteurs who took notes and recorded discussions using field notebooks.

Key informant interviews

Land owners, community leaders, village chiefs, headmen, youth leaders and women group leaders were asked to identify people they think were knowledgable on the relevant issues in their communities. They identified specific individuals deemed knowledgable in various aspects of the assessment, such as fish and fisheries, from their involvement in previous development projects at the local level. The names of these individuals were pooled, and the most popular ones were selected as key informants for semi-structured detailed interviews. Once the list of key informants in a given community was finalized, members of the RRA team were each assigned a key informant. Semi-structured interviews were conducted using lists of broad, open-ended questions. Using the guidance notes, the key informants were interviewed, and at the end of the exercise the responses were pooled together and analyzed. Key informants tended to be more frank when interviewed in private on their own farms. They were interviewed in a conversational, relaxed and informal way, which is said to be much more likely to yield in-depth opinions and perceptions than a closed-ended questionnaire interview (Barton 1997).

Ranking exercises

Ranking exercises were done with both groups (as in FGDs and the breakout sessions of the consultative workshops) and individuals as in the KIIs. The fish consumption preference ranking was conducted with groups, whereas the ranking of aquaculture production factors were done with groups and individuals. The ranking exercises enabled people to express their preferences and priorities about species of fish they like eating most and why. They were also able to rank factors affecting aquaculture site suitability, both individually with reasons and as groups with consensus reasons. Ranking exercises help planners understand how people make decisions about land and water use and look at the priorities of different groups regarding drinking, bathing, subsistence agriculture, vegetable gardening or cattle rearing (Townsley 1996).

For the fish consumption preference ranking, the groups were shown color photographs of fish and asked to arrange them in order of preference and give reasons for the arrangement. They were informed that they should point out if there was a fish they like eating that was not included in the photos. Individuals and small groups were more efficient in arranging the photos quickly than large groups. The facilitators supervised the exercise but did not interfere in the process. They only recorded the reasons and kept the papers in the order the group had arranged them. One member of the group would then explain the ranking and reasons to the larger group.

Factors and constraints on the adoption of aquaculture technology and production levels were also ranked individually and in groups. Individuals were asked to rank the first four constraints on fish production. They were then asked which constraints they would want addressed first if they had someone coming to help them.

SWOT analysis in stakeholder workshops

SWOT analysis is a method used to evaluate the strengths, weaknesses, opportunities and threats involved in a project or development undertaking. It involves specifying the objective of the project and identifying the internal and external environmental factors that are expected to help or hinder the achievement of that objective (Suh and Emtage 2005).

SWOT analysis involved gathering information from local farmers, governmental and nongovernmental agencies or officials on all strengths and weaknesses that existed at the time of this assessment. This was achieved through various means, including one-on-one interviews, FGDs with small groups and at a consultative workshop with the active participation of stakeholders and experts in the fields of aquaculture and agriculture. Once the strengths, weaknesses, opportunities and threats were identified and listed, the discussions were then centered around the following questions:

- How useful are each of the listed strengths to aquaculture development and production in Sierra Leone?
- How can listed weaknesses be overcome?
- How can identified opportunities be exploited?
- How can identified threats be defended against?

Economic evaluation of fish farming in fishponds

Estimating the costs and benefits of fish farming using ponds in this study was limited to the households, and the time value of money was taken into account with a discount factor. The broader benefits to society of better fed and more secure households were not considered nor were all the possible economic externalities (e.g. effects on water quality and aquatic biodiversity).

SWOT analysis in stakeholder workshops

The costs incurred by fish farmers in producing, processing, transporting and selling fish in the market were grouped as follows: pre-stocking costs; stocking, feeding and general management costs; and harvesting and marketing costs.

Pre-stocking costs

"Pre-stocking" expenditures, primarily consisting of land, tools and equipment, and labor, are costs incurred in securing land and constructing ponds as well as preparing them for stocking, such as liming and fertilization.

Cost of land

Most farmers did not pay for their land, because it was either family property or private land inherited from their parents. The market for land in rural Sierra Leone is not as well developed as it is in the cities, so the exact cost of agricultural land is hard to come by. In the absence of a well-developed market for land in the study areas, the opportunity cost of using land for fish farming (the annual rental value of land) was used in costing land as an input in fish farming.

The cost of building ponds on land where other crops could be grown was the maximum net income that could be realized if the pond site had been allocated to its best alternative use (L'Heureux 1992). The farmers would not justify allocating their plots of land for fish farming if their net profit did not exceed the net income they could derive from allocating those same plots of land to their best alternative use.

The most popular use of swampland where fishponds are commonly constructed is for rice farming and vegetable gardening. The opportunity cost of using land for fish farming was therefore rice and other crops that could not be produced from the same piece of land. The mean rice yield from four farmers in Tonkolili District, determined in the field, and the price of rice at the time of the study were used to estimate an average opportunity cost of using land for fish farming. Farmers reported that after they harvested their rice they either grew groundnuts, cassava or sweet potatoes. Estimates given by these four farmers indicated that the money equivalent derived from crop yields of any of the above crops or their mixture could be approximately half that of the main crop (rice). The annual cost of land used for farming fish was therefore estimated as follows:

*Cost of land (annual rent) = area of pond * rice yield * market price of rice * constant*

$$C_l = (A_l \times Y_r \times P_r)\ 1.5$$

Where C_l = cost of land per year (SLL)
A_l = total surface area of ponds (m^2)
Y_r = rice yield in bushels per m^2
P_r = price of rice (SLL per bushel)

A constant of 1.5 was introduced to account for any additional use of land, in between the rice crops, for producing vegetables or root tubers, which are estimated to yield half as much money as rice.

Costs of tools and equipment

Land clearing, pond construction and installation tools included hoes, shovels, "cutlasses" (machetes), pick axes, wheelbarrows and bamboo or PVC pipes (as pipelines for inlets and outlet pipes). Other tools and implements, such as scoop nets, fish pots or traps, hooks and lines, sticks, thatch and ropes, were included in the labor costs because they were fetched from the natural environment instead of being bought. The cost of each tool, its useful life and salvage value (where applicable) were recorded in the survey. Farmers used their tools for multiple production activities, not just fish farming.

The percentage use allocation to fish farming was based on the total number of farming activities undertaken by the farmer. The actual cost or depreciation values of the tools were shared among the various activities, and the proportion of the cost assigned to fish farming was derived follows:

$$C = \frac{(X_t - S_t)}{(N_t \times L_p)}$$

Where C = cost of implement for fish farming per year
X_t = total cost of a tool or implement in SLL
S_t = salvage value of the tool or implement in SLL
L_p = use-life of the tool or implement in years
N_t = number of activities for which tool was used by farmer

The total cost of tools used in fish farming per year was computed by adding the costs of all the tools used by farmers.

Labor cost for land clearing and pond construction

Constructing a fishpond involved land clearing, the pond layout or design, earthwork, and either a water system and pipes or a bamboo inlet and outlet. Pond construction constituted the major cost of fish farm development for the 200 farmers interviewed in the survey and took up the bulk of the construction period. Ponds were all constructed using manual methods. The labor cost was estimated as follows on the basis of the actual amount spent by some farmers who hired labor or the opportunity cost of farmers using unpaid family labor to construct the fishponds:

$$L_p = N_p \times d_p \times X$$

Where L_p = total labor cost in SLL per year
N_p = number of people employed or family members who constructed the pond
d_p = number of days spent constructing the pond to completion
X = amount of money paid to labor club members for one day of work per laborer

Stocking and general maintenance costs

Stocking costs included (a) the cost of obtaining and transporting fingerlings to the pond sites, (b) feed and manure collection costs, and (c) labor for brushing around the ponds and sometimes constructing a fence around them to prevent the fish from escaping.

Cost of fingerlings

Many farmers got their fingerlings freely or caught broodstock from the wild. Some other farmers reported getting a free supply from NGOs, government development projects, friends or relatives, while others stocked or trapped fish in their ponds during the rainy season and allowed them to reproduce or grow until the harvest during the dry season.

There were no standard stocking densities. The estimated number of fish stocked was multiplied by the local cost of fingerlings reported in the study areas for all farmers regardless of whether they reported paying for fish seed or not.

For the purpose of this assessment, if farmers caught the fish from the wild, they would have spent valuable time and energy in catching or trapping and transporting live fish into their fishponds. Farmers that used trap ponds could have also spent time making fences around the ponds to prevent trapped fish from escaping.

Time spent in such work was also considered as a general management cost. However, it was difficult to estimate the time spent hunting for broodstock from the wild or fixing structures to ensure that fish that swim into the trap ponds during flood waters cannot escape when the flood water recedes. Therefore, the actual cost of fingerlings from the government hatchery or other fish farmers was used as the total cost of fingerlings as follows:

$$F = N_f \times X_f \times P_y$$

Where F = total cost of fingerlings in SLL per year
N_f = estimated number of fish stocked or trapped in ponds
X_f = market price of one fingerling as sold in the government hatchery or by other fish farmers
P_y = number of production cycles per year

Feed and manure costs

The types of feed most often used were rice husk/bran and termites. There was no market for these products in the study areas. An alternative use for termites and rice husk/bran is in poultry and piggery, but here again farmers who used these inputs did not pay for them. Only a few people actually fed their fish, and even then only irregularly. The cost element for feed or manure added in this analysis was labor in acquiring it and putting it into the ponds. The cost of feed and manure was therefore estimated from the following:

$$CF = 0.15 \times N_{pc} \times X_l \times P_y$$

Where CF = cost of feed or manure per year
N_{pc} = number of times fish were fed within the growing season
X_l = labor cost for one day of work per laborer
P_y = number of production cycles per year

The constant of 0.15 was applied to account for the fact that farmers only spend about 15% of a workday hunting for termites or sweeping their kitchen or backyard to find rice husk or kitchen wastes to add to their pond. This also included time taken to transport the feed to the pond sites at a mean distance of 1.05 km from their house.

Costs of labor for general maintenance of fishponds

Maintenance work involves predator control through cleaning or brushing the area around the ponds and sealing the inlet or outlet pipes or channel to prevent fish from escaping. These costs were computed by asking farmers how many times they had to clean their pond(s) in a year and how long it took them to do so by multiplying the labor cost per day by the number of days of labor.

Harvesting and marketing costs

The main harvesting and marketing costs are the labor needed for harvest, the cost of gear (equipment) for harvest and the cost of marketing the fish.

Labor for harvesting

The fishponds were mostly harvested by family members, who were not paid. When farmers got help from nonfamily members, these helpers were given fish as gifts or compensation at the end of the harvest. The labor cost for harvesting was estimated as follows:

$$L_h = (N_h \times d_h \times X)\, P_y$$

Where L_h = total labor cost for harvesting per year
N_h = number of people who harvested the ponds
d_h = number of days spent harvesting the ponds
X_h = amount paid to one labor club member for a day's work
P_y = number of production cycles per year

Cost of gear

The cost of gear for harvesting was estimated from the following:

$$C_{fg} = \left[\frac{Q_{f1}(P_{f1} - S_{f1})}{N_{f1} \times L_{f1}}\right] + \left[\frac{Q_{f2}(P_{f2} - S_{f2})}{N_{f2} \times L_{f2}}\right] + \text{-----} \left[\frac{Q_{fn}(P_{fn} - S_{fn})}{N_{fn} \times L_{fn}}\right]$$

Where C_{fg} = total cost of fishing gear per year
Q = quantities of fishing gear (f_1, f_2---- *fn respectively*)
P = market prices of the different gear (f_1, f_2, -----*fn*)
S = salvage values of fishing gear (f_1, f_2, ---*fn*) respectively
L = average lifespans of the different types of gear (f_1, f_2, -------*fn*)
N = number of activities for which different types of fishing gear (f_1, f_2, ---*fn*) were used by farmers

Cost of marketing

Farmers sold most of their fish in their home villages, and most often fish were sold in one day. Fish reserved for home consumption were processed by the farmer. The labor cost for marketing fish considered wages to family members that sold the fish. Transportation cost was added in cases where farmers took fish to weekly or urban markets.

$$L_m = (N_m \times d \times X_m)\, P_y + T$$

Where L_m = total labor cost per year for selling harvested fish
N_m = number of family members involved in selling fish
d = number of days spent selling fish
X_m = amount paid to one labor club member per day of work
P_y = number of production cycles per year
T = transportation cost where necessary

Estimating gross incomes from fishponds

The gross incomes of farmers from fish farming were estimated by adding the quantities of fish recorded in partial harvests and the final harvest of ponds. The average prices reported by farmers who sold their fish at harvest time were then multiplied by these quantities as follows:

$$I = Q_f \times P_f$$

Where I = gross income in SLL derived from the sale of harvested fish

Q_f = quantity of fish harvested in kg
P_f = price of fish (SLL per kg)

Some farmers reportedly sold some fish midway through the production cycle but did not record the quantities. Rather, they recorded the amount of money made from such sales. This amount was added in the estimation of the mean gross incomes of farmers.

Economic data analysis

Classification of farmers into farm size categories

Because there are potential "economies of scale" in fishpond production, the farmer population was grouped by farm size. A random sample of 200 farmers was grouped into farm size categories using simple statistical tables and various size ranges until minimum standard deviations from the mean pond sizes were obtained for every group. This division was also carried out to verify if the theory of economies of scale for production is applicable to fish farming—namely that the larger the scale of production, the greater the profitability of production. Based on this criterion, pond sizes were classified as follows: 0–499 m^2 for small-scale producers, 500–999 m^2 for medium-scale producers and >1000m^2 for large-scale producers.

Net Present Value (NPV) of future cash flow calculations

The most important investment in the pond culture of fish is paid at the beginning of the farming period, but the benefits are accrued over long periods of time. The economic viability of fish farming was therefore measured more accurately by discounting the future monetary benefits and costs into present values. The present value calculations accounted for the time value of money and were carried out as follows:

$$PV = \frac{(FV)_t}{(1+i)^t}$$

Where PV = the value at time = 0
FV = the value at time t
i = the rate at which the amount will be compounded each year
t = number of years

The cumulative present value of future cash flows was calculated by adding the contributions of future values to the value of cash flow at time = t.

$$PV = \sum_{t=0}^{t} \frac{(FV)_t}{(1+i)^t}$$

The projected costs of production were estimated from the operational cost (variable costs) for 9 years of continuous production, assuming that the useful lives of the ponds were 10 years. The projected costs and returns were calculated to present values using an average discount rate of 20%, which took into account the high risk investment nature of fish farming in the country, in which the farmers were not insured and the risk of losing a whole year's investment if there is prolonged flooding is very high.

Similarly, natural predators and thieves could cause serious losses to farmers. The following components of future costs and benefits were discounted to present values as follows: (a) annual operating cost (cost of variable inputs) over the life of the fishponds, considering future inflation, and (b) annual revenue based on the expected yield and prices (assuming first year production was maintained).

Variable costs (running cost)

The projected operational cost after the first year was assumed as the difference between the total production cost and the cost of pond construction. The farmers did not buy any capital equipment and the cost of the simple tools used in their production system was depreciated to obtain the annual costs, which was used in the following calculations:

$$O_c = TP \, x \, PC$$

Where O_c = operating cost
TP = total production cost in the first year

PC = pond construction cost (fixed cost)

The operational cost was discounted for the different years to a maximum of 10 years.

Gross incomes estimations

The gross incomes of farmers were estimated by adding the farmer's proceeds from the sale of fingerlings, requested sales of fish before the main harvest (or partial harvest), sales of fish from main harvest, amount of money farmers would have received if they sold their farmed fish, and the amount of money farmers would receive if they sold the fish (fingerlings/broodstock) used for restocking ponds in the next production cycle.

Net incomes estimation

Net income was estimated from gross income minus total cost of production. The cost-benefit ratio was calculated as follows:

$$\left({}^{B}\!/_{C}\right) = \frac{\sum_{t=1}^{n} \frac{B}{(1+r)^t}}{\sum_{t=1}^{n} \frac{C}{(1+r)^t}}$$

Where B = the benefit = annual gross income (discounted to present value)
C = the cost = annual costs (discounted to present value)
n = maximum length of time in years
t = time in years
r = discount rate
If $B/C > 1$, fish farming is economically viable (profitable)
$B/C = 1$, break even (cost recovery)
$B/C < 1$, fish farming is not profitable (not economically viable or loss)

Payback period calculation

The benefits of fish farming are accrued over time, so the payback period was calculated to account for the effect of time on investment in the analysis. The payback period is the time it takes for the benefits of fish farming to repay the costs or investment.

$$P_i = \frac{C_i}{R_a}$$

Where P_i = payback period in years
C_i = cost of investment in SLL
Ra = mean annual net returns in SLL

The payback period is often known as the breakeven point and is sometimes more important than the overall benefit of an investment for farmers who borrowed money to invest in fish farming.

Key findings and results

Sample size and distribution of fish farmers in the aquaculture baseline studies

The aquaculture baseline study commissioned by FAO (Showers 2015) sampled 262 fish farmers from four districts, namely Tonkolili, Bo, Kenema and Kono districts (Table 3). Of the sampled farmers, 52% were from Tonkolili and another 34% were from Bo. The remaining two districts of Kenema and Kono accounted for less than 15%, likely because they have few fish farmers.

This aquaculture assessment study aimed at documenting all existing fishponds in Tonkolili and Bombali districts, whether in active production or abandoned. To do this, the GPS positions of all existing fishponds were documented. Data on the construction, ownership and size of the ponds was also recorded in the survey.

The sample size for the information on productivity of the ponds was 200 and was based on the mean quantities of fish actually harvested by farmers and the fish prices at the time of harvesting. These values were then multiplied by the average number of production cycles per year.

Gender participation in fish farming

In the FAO aquaculture baseline survey, 92% of all farmers sampled were male and only 8% were female (Table 4). This was a reflection of the fact that fish farming is a labor intensive and highly technical activity, particularly the construction of the ponds. Women are more active in stocking, managing, feeding, harvesting, processing and marketing fish. Physical ownership of fishponds is most often by men. Another reason for male dominance in fishpond ownership is that women find it more difficult to have secure access to land. Traditionally in rural Sierra Leone, women do not inherit land from their parents. Even in Tonkolili District where most fishponds are located, ownership was 80% male and 20% female.

District	Number of respondents
Bo	89
Kenema	22
Kono	15
Tonkolili	136
Total	**262**

Table 3. Aquaculture baseline survey sample in the five districts.

Sex	Number of respondents
Male	241
Females	21
Total	**262**

Table 4. Gender composition of fish farmers in the five districts sampled for the FAO aquaculture baseline and WorldFish aquaculture assessment surveys.

Age composition of fish farmers

The age of the farmers ranged from 18 to 95 years old, for an average of 46 (Table 5). The age of household heads mostly fell between 40 and 60 years old. These were mature adults with years of experience already in administration and business.

Marital status of fish farmers

The majority of farmers interviewed in the FAO aquaculture baseline survey were married males. One-third were in polygamous marriages (33%) and 38% were in monogamous marriages (Table 6).

Age	Age in years
Maximum	95
Minimum	18
Average	**46.86**

Table 5. Age composition of fish farmers in the five districts sampled for the FAO aquaculture baseline and WorldFish aquaculture assessment surveys.

Marital status	Number of respondents
Married monogamous	101
Married polygamous	87
Separated	1
Cohabiting	13
Single	48
Widow	4
No value	8
Total	**262**

Table 6. Marital status of fish farmers in the five districts sampled for the FAO aquaculture baseline and WorldFish aquaculture assessment surveys.

Main occupation of fish farmers

Nearly 80% of the fish farmers interviewed were mainly crop farmers while 4% were teachers. The rest of the respondents were of various professions or simply unemployed (Table 7). The fact that many crop farmers, particularly in Tonkolili District, took up fish farming may be because the technology may have been introduced in the 1970s and early 1980s as part of agriculture extension (livestock rearing), so the target beneficiaries have mostly been crop farmers.

It is also worth noting that majority of the farmers (76%) were motivated to go into fish farming mainly for household consumption (Table 8). Most development partners and NGOs have supported aquaculture in Sierra Leone as food security and nutritional support or as a means for crop farmers to diversify their livelihoods and income earning activities. It is also unsurprising that most of the fish farmers sampled were not practicing commercial aquaculture production, because they were all subsistence crop farmers.

Occupation	Number of respondents
Farmer	206
Livestock rearing	6
Civil servant	5
Fishers	2
Clergy	1
Healthcare	1
Agro-rader	1
No value	7
Finance real estate	1
NGO worker	1
Native doctor	1
Other (not specified)	3
Teacher	10
Others professional (e.g. lawyer)	2
Petty trader	4
Service worker (e.g. waiter, maid, cook, caretaker)	1
Small business owner	1
Spinner or weaver	2
Student	1
Trade worker (e.g. carpenter, mechanic, blacksmith)	3
Too old to work	1
Unemployed	2
Total	**262**

Table 7. Main occupations of fish farmers in the five districts sampled for the FAO aquaculture baseline and WorldFish aquaculture assessment surveys.

Reason/motivation for doing fish farming	Number of respondents
Household consumption	200
Other reasons	44
No values	10
Entered as 4 (coded)	8
Total	**262**

Table 8. Drivers or motivation for doing fish farming in the five districts sampled for the FAO aquaculture baseline and WorldFish aquaculture assessment surveys.

Commercial fish farming is more readily successful with large-scale investors with the necessary capital in urban and peri-urban areas. There likely needs to be a change in approach, whereby entrepreneurs and small- to medium-scale businesspeople are targeted for aquaculture promotion in urban and peri-urban areas. Rural aquaculture promotion for food security and nutrition would still continue to target poor rural farmers who have free access to suitable land and water resources to practice aquaculture.

Religious affiliation of fish farmers

Muslims made up 71% of fish farmers interviewed in the aquaculture baseline survey while 24% were Christians (Table 9). Religious affiliations have implications for fish consumption patterns and religious taboos about food (see details in subsequent sections). Religious festivities for Eid, Christmas, Easter, etc. are also significant in terms of fish market demand and consumption during these festivals, in addition to other traditional festivities celebrated throughout the country.

Ethnic groups of fish farmers

Temnes and Mendes were the dominant tribes involved in fish farming in the five districts sampled (Table 10). The two tribes comprised 86% of the fish farmers interviewed in the survey. Other tribes, such as Kono, Fulah and Krio, were in the minority in fish farming practice.

Religion	Number of respondents
Muslim	186 (71%)
Christian	63 (24%)
Others (nonbeliever, traditionalist)	4 (1.5%)
No values	9 (3.5%)
Total	**262**

Table 9. Religious affiliations of fish farmers in the five districts sampled for the FAO aquaculture baseline and WorldFish aquaculture assessment surveys.

Ethnic group	Number of respondents
Temne	130 (50%)
Mende	94 (36%)
Fullah	4 (1.5%)
Limba	1 (0.3%)
Kono	17 (6.5%)
Krio	4 (1.5%)
Koranko	1 (0.3%)
No value	7 (2.5%)
Arabic	1 (0.3%)
Sherbro	3 (1.1%)
Total	**262**

Table 10. Ethnic groups involved in fish farming in the five districts sampled for the FAO aquaculture baseline and WorldFish aquaculture assessment surveys.

Pond ownership categories

Individuals owned 85% of the fishponds recorded in Tonkolili and Bombali districts by the aquaculture assessment study, whereas 14% were community owned (Table 11). Government and organized groups combined had only about 1% of the recorded fishponds.

The FAO survey found that land tenure and ownership affect farmers' motivation to invest time and money to construct fishponds. It further revealed by the FAO survey and the aquaculture assessment study that individuals owned 93% of ponds in the five surveyed districts (Bo, Tonkolili, Kenema, Kono and Bombali), while groups or communities only owned the remaining 7%.

Results of this assessment show that there has been a shift from largely community fishpond ownership to individual or family ownership. It is also interesting to note that a significant number of fish farmers have not been supported by donors or NGOs to go into fish farming. It is encouraging that many fish farmers are now constructing fishponds on their own initiatives (Table 12 and 13).

Fishpond ownership	Number of ponds	Percentage
Individual and family	1,777	85.15
Community	289	13.85
Government	16	0.77
Group/association or institution	5	0.23
Total number of ponds in Bombali and Tonkolili	2,087	100
Number of operational fishponds in Tonkolili and Bombali	251	12
Number of individual ponds owned by women	347	19.5
Number of individual ponds owned by men	1,431	80.5
Number of operational ponds owned by men	106	42.2
Number of operational ponds owned by women	25	10
Number of operational ponds owned by communities	84	33.5
Number of operational ponds owned by government	16	6.4
Number of operational ponds owned by families	20	8.0
Community ponds not supported by NGOs/donor agencies	254	87.9
Community ponds supported by NGOs/donor agencies	35	12.1
Individual fishponds supported by NGOs/donor agencies	334	18.8
Ponds supported by NGOs and still active during the assessment	7	1.9
Individual fishponds not supported by NGOs/donor agencies	1,417	81.2

Table 11. General fishpond ownership in Bombali and Tonkolili districts.

District	Chiefdom	Community	Family	Government	Individual	Organized group	School	Total
Bombali	Gbendebu Ngahun				22			22
	Pakiemasabong	6						6
	Safrokor Limba	1	1					2
Tonkolili	Gbonkolenken	21			12			33
	Kafe Simra	2			1			3
	Kolifa Mabang	1						1
	Kolifa Rowala	19			2			21
	Konike Barina	81	11	16	933	3		1,044
	Konike Sanda	142	15		763	1	1	922
	Tane	12			17			29
	Yoni	4						4
Total		**289**	**27**	**16**	**1,750**	**4**	**1**	**2,087**

Table 12. Fishpond ownership by chiefdoms in Tonkolili and Bombali districts.

Chiefdom	Total number of ponds	Operational ponds	Average pond area (m²)	Ownership
Tonkolili District				
Gbonkolenken	33	12 operational 21 abandoned	295.19	Community: 21 Individual: 12
Kolifa Rowala	21	2 operational 19 abandoned	388.79	Community: 19 Individual: 2
Kafe Simra	3	2 operational 1 abandoned	292.63	Community: 2 Individual: 1
Kolifa Mabang	1	1 abandoned	600	Community: 1
Yoni	4	2 operational 2 abandoned	220.42	Community: 4
Konike Barina	1044	103 operational 941 abandoned	335	Community: 81 Individuals or family: 939 Government: 16 Groups or associations: 3 No information: 5
Konike Sanda	922	128 operational 794 abandoned	378.67	Community: 142 Individual and family: 776 Muslim Jamat: 1 School: 1 No information: 2
Tane	29	29 abandoned	380.99	Community: 12 Individuals: 17
Bombali District				
Safroko Limba	2	2 abandoned	380.99	Individual: 1 Community: 1
Gbendebu Ngahun	22	22 abandoned		Formally owned by individual but now dead
Paki masabong	6	2 operational 4 abandoned		Community: 6

Table 13. Numbers, ownership and operational status of ponds in different chiefdoms of Tonkolili and Bombali districts.

Important socioeconomic and political factors affecting aquaculture development

Some key socioeconomic factors were important with respect to technology adoption and increased productivity of fish farms in Sierra Leone as recorded by Sankoh (2009).

- Household characteristics or demography (active/inactive by household) play an important role.
- Political structures (local and national government structures) and policies affect the availability of aquaculture inputs and support services.
- Investment climate and economic growth affect aquaculture investment opportunities and ensure that aquaculture inputs and supplies are available to fish farmers and affect farmers' access to credit facilities.
- NGOs support policies that may provide incentives and trigger or support aquaculture development, management and productivity.
- Social structures, including family and household structures, could serve as or provide official and unofficial sources of inputs, labor, credit, land access and control.
- Gender roles are important in household farming time management.
- Food customs and taboos can affect market demand for fish and other animal protein foods (Figure 1).

Household characteristics and demography

Household characteristics have a direct impact on the household labor force that may be available for the hard work of clearing land and constructing ponds. FGDs in Tonkolili and Bombali districts found that many households are large, as did Sankoh (2009). Fish farmers consider this an advantage because manual labor is needed for farming activities, so small families or households were considered to have fewer hands or a small labor force. As a result, the extended family system is viewed as a way of having many family members cooperate in the farm work (see Figure 4). Individuals in small families or households often join labor clubs so that farm work can be done cooperatively in the absence of many family members.

Historical, political and social context

Historical context

Western colonization, democracy, education and religious influences contribute significantly to the dilution of some of the cultural practices and traditional authorities in Sierra Leone in general and the two districts of interest in particular (Sankoh 2009). Existing sociopolitical, economic and cultural settings recorded in Sankoh's study areas posed challenges, which must be recognized and systematically addressed in any aquaculture project design and implementation.

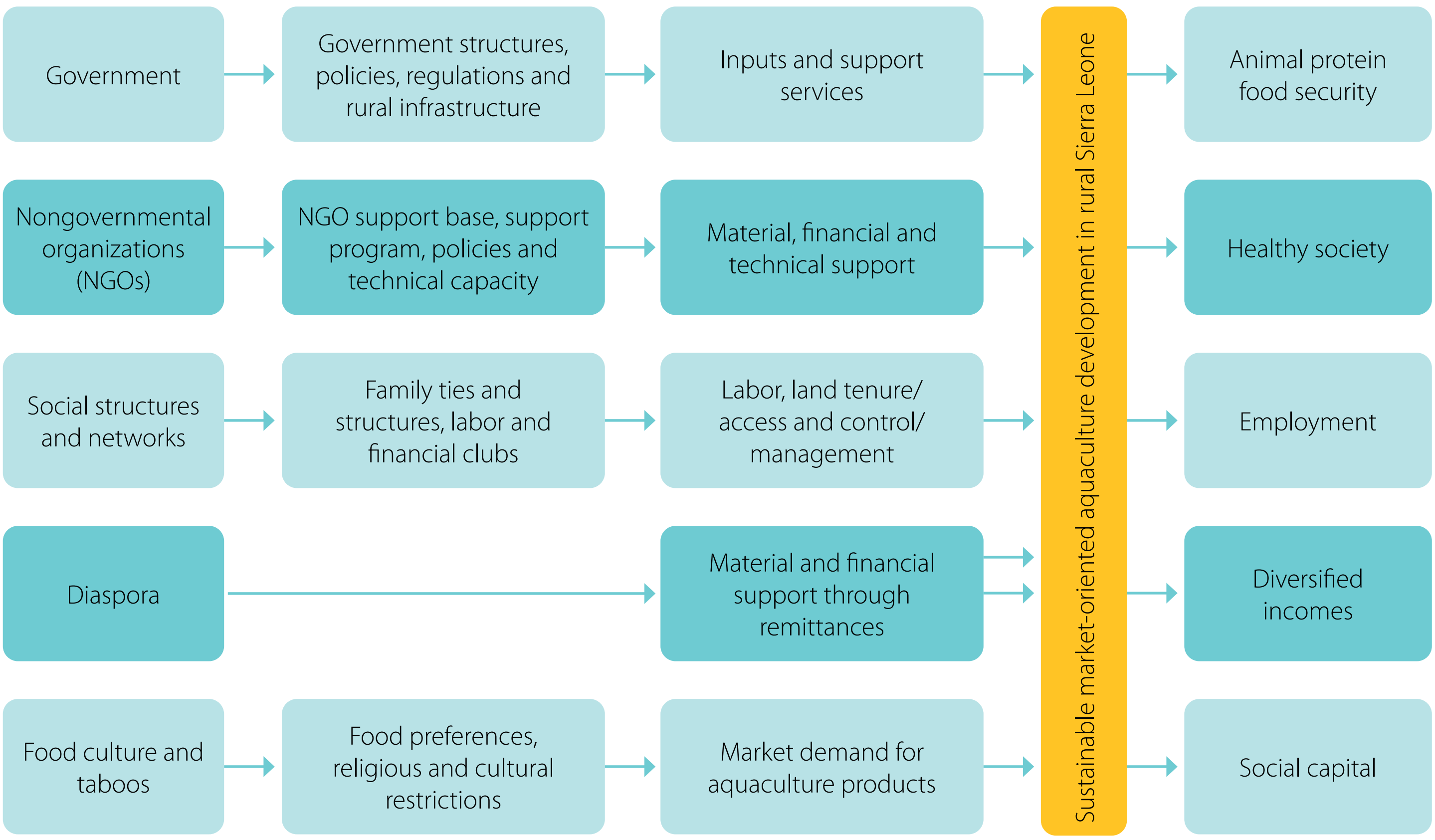


Figure 1. Contribution of socioeconomic and cultural factors to aquaculture development and potential benefits derived therefrom (Sankoh 2009).

The political structures in Sierra Leone are partly a reflection of the legacy of British colonial rule. The British colonial masters had a dual governance structure whereby Freetown was maintained as a colony and the provinces as a protectorate. Land in the colony was considered crown land, owned by the Queen, and could be held as freehold. Land in the provinces was held in trust by the paramount chiefs but owned by families. After independence in 1961, the paramount chiefs, section chiefs and village chiefs remained significant political figures (Figure 2). The implication of this legacy of direct and indirect rule on aquaculture is that investors who have the required capital for aquaculture production cannot easily access land and water resources in the provinces.

Politics (central and local government)

The GoSL has a Ministry of Local Government and Rural Development under which there are district councils and three resident ministries, for the Northern, Southern and Eastern provinces. The Local Government and Rural Development Act of 2004 devolved the responsibility of licensing the development of artisanal fisheries and aquaculture to the local councils. This responsibility was formally under the MFMR. The local councils have no capacity for managing aquaculture development or artisanal fisheries apart from the collection of license fees from commercial operators.

Figure 2. Political map of Sierra Leone with districts and chiefdoms (Source: Statistics Sierra Leone).

The three provinces are divided into 12 districts (Figure 6), with a district officer governing each one. The districts are further divided into chiefdoms, which are governed by 149 paramount chiefs, of which 12 (one from each district) are members of the parliament. The chiefdoms are divided into sections (groups of four to 10 villages). Each of the sections is ruled by a section chief, appointed by the paramount chiefs from a ruling family (in some places several families take turns supplying a chief) (Figure 3).

Villages have either a chief or a headman. Other important people in villages include religious leaders (chief imam of the mosque and pastor of the church). Where secret societies and other institutions exist in villages, they have institutional or society leaders with different titles depending on the institution or society. In addition, villages with many young people normally have youth leaders who acquire leadership roles from their social and labor club activities. The hierarchical structure of the communities translates down to the family and household level (family head and household head). The families are mostly patriarchal and the household heads are mostly men.

Political implication of aquaculture development

The most important roles of government in aquaculture development include

- infrastructure development (e.g. roads, market centers and agri-business centers) and support services (extension services) facilitating input supplies;
- negotiating land leases for commercial developments, such as commercial farming as operating in mining enterprises;
- creating a conducive regulatory and investment climate, such as tax incentives for large-scale investments in aquaculture and related businesses like inputs supply;
- educational policies and training arrangements to ensure trained and qualified professionals are readily available to take up jobs that may be created by the private sector.

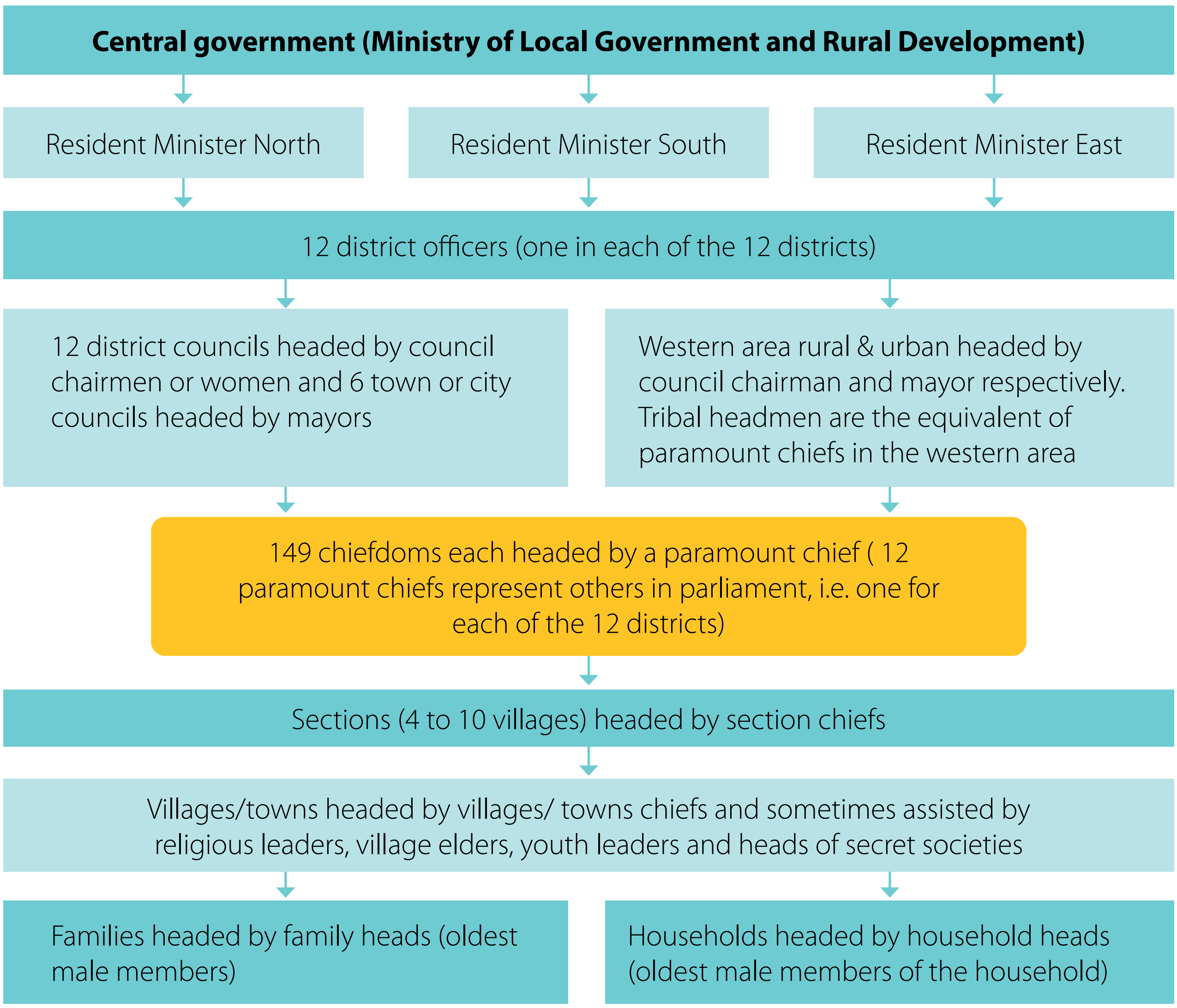


Figure 3. Political and social structure of rural Sierra Leone and its relation to the central government in Freetown (Sankoh 2009).

Investment by the central government in infrastructure development and the provision of basic inputs and support services and social services affect farmers' access to such services and so determines where aquaculture can develop faster or become more widespread. Similarly, government can effectively negotiate acceptable lease agreements for land access by commercial agriculture or aquaculture investors on behalf of land-owning families. An example of such agreements is the Sierra Rutile Mining Company surface rent agreement negotiated by the GoSL on behalf of land-owning families with the company (Sankoh 2009). This agreement stipulates that the company must pay an amount known as surface rent (USD 10/acre of land per year) to the central government, who then distributes it as follows:

- 40% to the land-owning family
- 20% to the paramount chief of the chiefdom where the land is located
- 20% to the district local council
- 20% to the central government.

Although USD 10/acre/year of fertile agricultural land is less than a tenth of the value of the land for agriculture (Wadsworth, personal communication, 2016), this amount can be negotiated upward depending on other considerations of employment opportunities for children of the land-owning families and cooperating in social responsibilities. If properly negotiated, these arrangements are applicable to investment in agriculture, such as the ADAX bio-energy project, which produced sugar cane and ethanol. This land lease, or surface rent as it is called in the mining sector, might be applicable to large-scale aquaculture investment.

At the village level, fertile land resources for agriculture production belong to the ruling families (chiefs and their families). Social norms, networks and institutions allow polygamy, especially among powerful members of the communities. Similarly, over 70% of the rural people are Muslim, and Islam allows polygamous marriages. Landless community members exploit these norms and religious practices by arranging "forced" marriages in villages to gain temporal access to land resources belonging to their in-laws. A "rich man" (in terms of land resources) in the village is given many wives, so the parents of the wives can gain temporary access to the rich man's land resources.

Government could also trigger or promote aquaculture investment from the private sector through the provision of tax incentives and a conducive investment climate or enabling environment. The public education system should allow for the production of the required skillset to support aquaculture development and growth. At the time of this assessment, the University of Sierra Leone had only one aquaculture expert at the Institute of Marine Biology and Oceanography, and Njala University only had two, one of whom was Nigerian. Although both universities are producing graduates in marine sciences as well as aquaculture and fisheries management, the minimum required training for the certificate level for aquaculture technicians and hatchery managers is lacking throughout the whole country (2016). The government needs to reverse this situation to produce the minimum pool of skills required to trigger aquaculture development and growth.

Social institutions and structures

Labor and financial clubs

Labor and financial clubs are social networks formed within rural communities as coping strategies. The labor clubs are ready sources of farm labor that are used in farm production for farmers who do not have money to pay for labor. Different labor clubs were reported for various farming tasks, and memberships varied from one village to the other. Generally, labor groups formed for selling labor tended to be large (15–20 strong workers). Richards et al. (2004) gave a detailed description of the different forms and functions of labor and financial clubs in some areas of rural Sierra Leone. Many of the farmers who were recorded to have more than one fishpond said they had hired labor clubs to construct fishponds for them in Tonkolili District.

Similarly, financial clubs, called *osusu*, were reported to be very useful credit and investment methods. The members of a financial club contribute money on a weekly, monthly, annual or biennial basis and give this to one member on a rotational basis. Club members are therefore able to access reasonable sums of money without interest and can invest this in fish farming and other agricultural production. The informal financial clubs have been formalized into financial services associations (FSAs) by MAFFS. Rural farmers find it difficult to raise capital through formal banking systems for the following reasons:

- "Rural banks" or community banks were only introduced in Sierra Leone after the war (about 2005).
- "Westernized" banks are unwilling to lend money to poor rural farmers who do not have collateral. They do not have title deeds for the family land they use, there is little market value for their houses, which

are built of local materials, and they only have a few livestock, so the above social structures (labor and financial clubs) are reportedly very useful (Sankoh 2009).
- The interest rate for commercial banks is too high (20%–30% annually) for poor rural farmers to pay back if their only investment is in fish farming at the current level of investment, which has little chance of being financially viable.

Family

Extended family systems are common because extended family often live together in the same house. In a few cases, big family houses cannot accommodate all of the members of an extended family, so smaller houses are constructed nearby to form "family compounds."

Family lineage is patrilineal. Usually the oldest and strongest living male member is the head of the family, and when he dies the next oldest brother becomes the head. In the 2004 national census, women headed about 10% of households. The lineage group administers its joint property, notably farmland. Family members assemble before the start of each agricultural cycle to agree where they will make their farms for the year since they almost always grow annual crops. A schematic representation of a family and household structures is given below (Figure 4).

Households

Rural households in Tonkolili and Bombali districts, also known as *kafoos* in Temene, are the farming (economic) unit of the family. The households are composed of family members who work on the same farmland throughout the year and eat food cooked daily in the same pot. In urban areas, household members live in the same house or flat and share food and household chores. Often they are from the same family, but with the extended family system, one family can often break up into several households if all the family members cannot all fit into the same house. When the extended family gets too big, the family splits up into several households (or farming units), depending on the number of grown up male children in the family. Generally, these smaller units have the mothers as figureheads.

In Figure 4, households 2 and 3 comprised the first and second wives of the head of the family, respectively. The wives both have grown up male children who could make their own farms. Guided by their mothers, they would be given plots from the family land to make their farms by the head of the family (the oldest male child in the family), and their mothers would cook for them if they were not yet married.

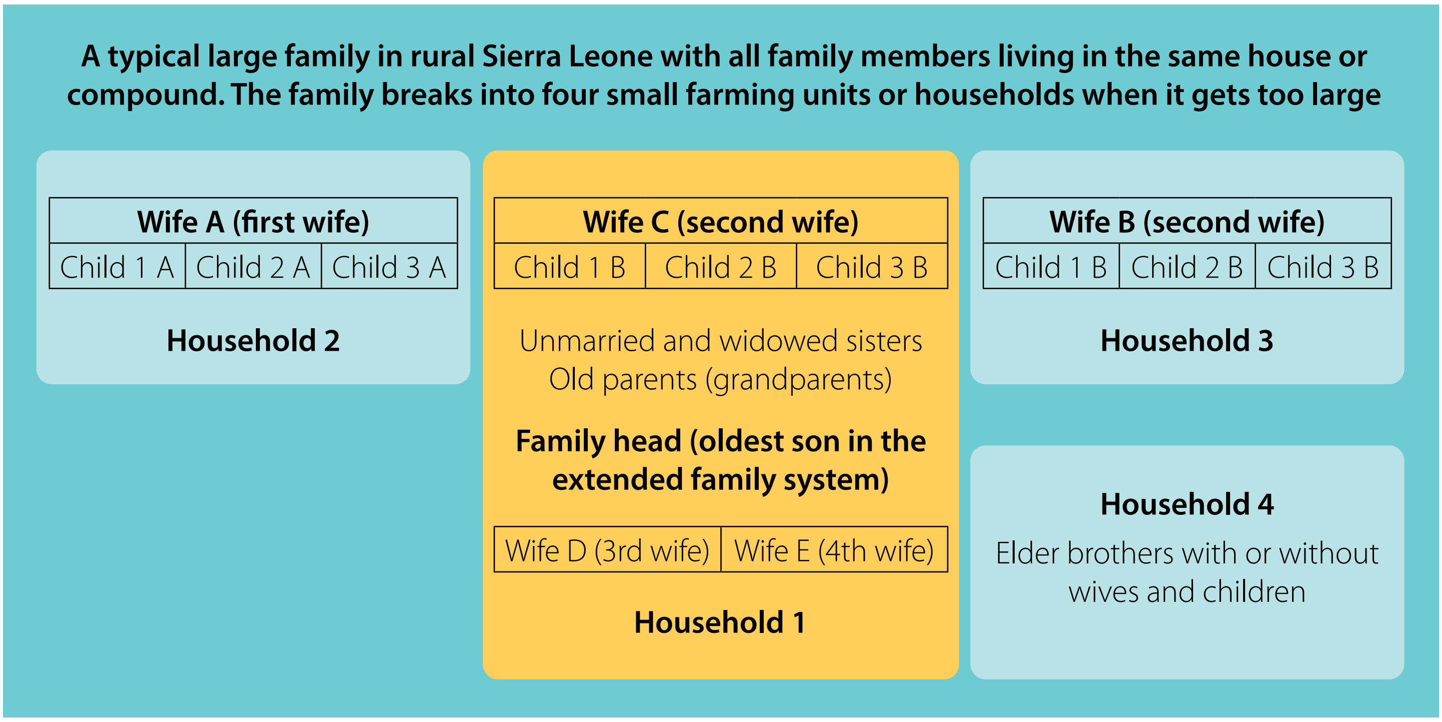


Figure 4. A typical rural family in Sierra Leone (Sankoh 2009).

Wives 3C and 4D are the junior wives, and the children are too young to be able to make their own farms. These junior wives and their children are strongly dependent on their husband/father. Together, they form the main household (household 1). Every member of the family contributes labor to the main household farm.

The ideal family is large, often over 20 members, and stays in the same village but in different houses. Usually, female children 15 years old and above leave when they get married, though male children often stay even after marriage. This is probably because the father maintains control of the family land until he dies before the eldest male child takes over. The number of households and therefore farming units per family is dependent on the number of grown up male members. Women were recorded as saying, "I cannot make my own farm because my son is small" or "because my son is going to school in the city."

A key informant interviewed Pa Sorie Gbla, in the village of Manasie in Tonkolili District, who pointed out that women who are not blessed with male children in the villages are very sad women. If parents had only female children, they would insist that the female children get married in the same village so that their sons-in-law could help them with farm work. Women without children usually "adopt" relatives' children, though formal legal adoption is rare.

Local moneylenders consider wives and children collateral for guaranteeing loans in rural Sierra Leone. The FGDs for this study revealed that rural society's general perceptions are that a man with a wife and children cannot easily run away from his village to escape debts. Similarly, single women cannot easily access land resources or loan facilities. FGDs revealed that having a large number of children and wives in rural Sierra Leone is considered advantageous because large families offer some security. Also, farm work is easier with more hands. Having many wives and children is perceived as a symbol of wealth, social kingship and dignity in many rural communities in Sierra Leone.

Influence of the Sierra Leonean "diaspora"

It is unknown how much money is sent to Sierra Leone from friends and relatives living overseas. There is some informal information that it could be as much as three times the official aid budget, but the actual amount is unknown. Anecdotal evidence suggests that relatives living overseas often fund capital items like chainsaws, vehicles or motorcycles (*okadas*). It is expected that support from this subsector of the economy might play a supporting role in fish farming activities in the rural areas (Figure 5).

Influence of development partners and NGOs

Although not part of the government, development partners and NGOs have a major impact on development, especially in agriculture. In the 1980s, virtually the whole of Sierra Leone was covered by integrated agricultural development projects (IADPs) funded by the International Fund for Agricultural Development (IFAD), the World Bank and the German Technical Cooperation Agency, among others. Single-issue development projects were funded through food for work projects. Since the end of the civil war in 2002, there has been a gradual increase in the return of such international NGOs, though not to the same extent. A number of local NGOs and community-based organizations exist but are for the most part poorly funded.

Food, customs and culture

Rice is the staple food and the main meal of the day in Sierra Leone. Wide varieties of fruits and tubers (e.g. potatoes, cassava, yam) are also eaten, but these are often considered "snacks." Rice is prepared with a variety of sauces made from some combination of potato leaves, cassava leaves, hot peppers, peanuts, beans, okra, fish, beef, chicken, eggplant, onions and tomatoes, collectively called "rice and plasas," "rice and soup" or "rice and stew." Dried or smoked fish is an important and common component of these dishes.

Food is often abundant in the dry season, from October, when the upland rice farms are harvested, to December, when the swamp rice is harvested. Between January and April, tubers, maize and vegetables are the main produce.

Large quantities of food (mostly rice) are prepared at weddings, funerals, initiations, memorial services and other public gatherings, most often in the dry season, and guests usually eat until they are all full. Hosts would feel ashamed if a guest was perceived not to have had enough food. A portion of food prepared for such occasions is sometimes offered to ancestors in recognition of their spiritual presence and continued guidance to the living.

Seasonality was also recorded in fishing and fish harvests. People living in the interior of Sierra Leone, particularly in villages, mostly rely on freshwater fish in the rainy season. In the dry season, they get marine fish, mostly small pelagics, such as bonga (*Ethmalosa* *fimbriata*), flat herring (*Sardinella madarencsis*) and latti (*Ilisha africana*). In Tonkolili and Bombali districts, women are often seen going to streams or swamps and floodplains in the rainy season with their scoop nets or fish pots/traps to catch fish that come to spawn in these plains. In the dry season, fishponds and fish holes that could not normally be drained during the rainy season are drained and the fish in them collected mostly by women.

Male children are also often involved in catching fish during the rainy season using hook and line. Food supplies, including fish, are generally low in the rainy season and plentiful in the dry season.

Livestock, normally kept as free-range, flourish in the rainy season when the fields are covered with green grass and suffer in the dry season when the grasses are all dry in the fields. Poultry, which are also kept free-range in the villages, do well in the dry season when the farm crops are harvested and processed.

Villagers in the two districts preferred selling their chicken and eggs than eat these as sources of protein. They would rather sell chicken, livestock (mostly goat and sheep) and use the money to buy fish.

Religious taboos about food

Common religious taboos recorded in the assessment include restrictions against eating some kinds of meat or food prepared in certain ways. Some of the taboos are related to religion (e.g. Muslims do not eat pork, nor do they eat nonhalal meat or animals that died naturally). Some families or individuals do not eat monkey or duck meat. Electric fish (*Malapterurus electricus*) and some species of snakes (pythons) are taboo to some families. Violations of these taboos are often considered sinful for Muslims. They are also seen as bad luck for traditionalists because of associated ill feelings of the spirits of the dead.

Food habits and customs are favorable for large-scale fish farming in Sierra Leone, because the dry season ceremonies of initiations, memorial services, weddings, child naming ceremonies and other public gatherings would be ideal times to harvest and sell fish if production is synchronized with these activities. Similarly, farming periods, during which labor clubs are cooked for by every member for whom they work, could also be synchronized with harvesting for fish farms.

Muslim taboos of nonhalal meat only apply to meat/beef. Most rural people eat bush meat because they cannot afford meat from livestock. All fish are considered clean and acceptable for consumption by all ethnic groups and faiths in the country because they are obtained from water. The only exception is electric fish, which were identified as taboo to a few individuals and families or possibly caused allergies in some people.

Assessment of local technical knowledge on fisheries and fish farming

Local people have a wealth of unconsolidated knowledge on fish and fisheries, but most useful knowledge is not easily shared with strangers, either because of secret society rules or because there is nothing to guarantee intellectual property rights. This valuable knowledge is transferred vertically, from parents to children, with very horizontal propagation within the general public, because if local knowledge were shared, benefits to the knowledge holder would be at risk. In these impoverished rural communities, knowledge is considered wealth, but few people are willing or able to pay for it, and many of the knowledge holders are not willing to share it freely. The principle of secrecy may be likened to copyright or anti-piracy laws in the Western world, which prohibit illegal copy or sharing of knowledge without permission from the originator.

Local knowledge on fish ecology and behavior and its use in traditional farming systems are at risk of extinction because it is not propagated horizontally. In areas where life expectancy is low, and parents die when the children are still young, knowledge is most likely lost. Also, massive rural urban migration of the youth could mean that children may not be able to learn from their parents who are living and continuously interacting with their natural environment. If old people die without passing on their knowledge to their children and grandchildren, such knowledge will become extinct. Therefore, there is an urgent need to undertake a systematic and comprehensive documentation of the local knowledge base of rural communities in Sierra Leone. There is also an urgent need to encourage and promote the use of such knowledge in farming systems and other livelihoods alongside modern technology, because such integration has produced more sustained outcomes in development efforts.

Local knowledge on taxonomy of fish species

Most ethnic groups, especially in fishing communities, have developed a sophisticated classification system for fish. Fish naming in local languages is based on multiple criteria. The local system of classification whereby the names are not recorded in books but transmitted to future generations orally is easy to remember because it is based on the physical appearance and behavior of fish.

For some fish, the family name is generally applied to all species belonging to that family and an additional name added based on habitats where the fish are commonly found, their behavior or physical appearance (Table 14). "Traditional classification systems are similar to the taxonomic concepts in the biological sciences; because both systems satisfy the same 'demand for order'" (Silva 1997). The knowledge of local fishers on fish classification and taxonomies using local names are relevant for stock assessment and a valuable basis for biological studies. The development of a complex fish naming system and classification of fish behavior is based on long-term empirical observation. It also guides the behavior of the people in a community with regards to farming and fishing strategies and is essential for predicting situations where farming or fishing can be successful.

The general Mende name for catfish is *maboboi*, which literally means "slippery fish." Different species of catfish are given different names depending on their physical appearance, behavior, stage of development and habitat where they are commonly caught.

The carnivorous fish *Hepsitus odoe* is called *gingbi* (biting fish) in Mende. In Limba it is called *ba thain* (dogfish), because dogs are carnivores and hunt other animals just as *Hepsitus* feed on other fish. The Temnes call it *ka thin* (jumping fish), because this fish has a habit of jumping over small fishing boats or nets.

Mendes and Temnes have also developed different names for juveniles and adults of some species of fish. For example, *antootook* is the young of *antumil* (*Heterobranchus bidorsalis*).

Synodontidae are generally referred to as *gbokbo* in Temne, describing the strong heads and spines. This name is followed by a second name or suffix that describes the color of the fish: *fayrah* ("white") referring to silvery color, *bi* ("black") for the dark or gray color, and *yim* ("brown") for the brown color.

The Mende and Temne classification systems for fish use fish characteristics like electric shocks of the electric fish, which is called *gbi-gbi* in Mende, literally symbolizing the electric shock felt when touching an electric fish. Limbas use the same name, while in Temne it is called *danink* ("shocks").

English name	Mende name	Limba name	Temne name	Notes
Freshwater catfish (*Clarias species*)	*Maboboi*		*Antumil* or *Makone*	Literally meaning "slippery fish" (fish without scales). Different species of catfish are given varied names depending on physical appearance, behavior, stage of development and habitat where the fish are commonly caught. For example, *harlay* is the Mende word for juvenile catfish while adults are called *makonde*, but both are generally put under slippery fish.
Dogfish (*Hepsetus odoe*)	*Gingbi*	*Bathain*	*Kathin*	The Mende name means "biting fish," the Limba name means "dog fish" and the Temne name means "jumping fish."
African catfish (*Heterobranchus bidorsalis*)	*Harlay* (juveniles) *Makonde* (adults)		*Antutuk* (juveniles) or *Antumil* (adults)	Juvenile fish have different names than adults of the same species.
African rock catfish (*Synodontis bastiani*)	*Gbelui*	*Gbokbo*	*Kagbokbo*	Strong head and spines.
Electric catfish (*Malapterurus electricus*)	*Gbigbi*	*Gbigbi*	*Danink*	These names symbolize the electric shock felt when touching an electric fish. Limbas use the same name as Mendes for electric catfish.

Table 14. Examples of local names of fish recorded in the aquaculture assessment survey in Tonkolili and Bombali districts.

Local knowledge on fish ecology and behavior

Local fish farmers and fishers in Tonkolili and Bombali districts have extensive knowledge of the ecology, behavior and feeding habits of fish. This knowledge is applied in different fishing methods used to exploit wild stocks and in traditional fish farming systems. Local knowledge on fish behavior, ecology and fishing/fish farming is culturally produced and accumulated through practice, and it is continually recreated according to the features of the aquatic environment, which is cyclical, mobile and unpredictable.

The following three examples of "walking catfish," "burrowing fish," and feeding and spawning areas exemplify local knowledge on fish ecology.

"Walking" catfish

Some farmers and key informants explained that freshwater catfish (*makone* in Temne and *maboboi* in Mende) can move out of the stream onto land in search of food and actually enter into fishponds during the early stages of the rainy season. The fish are said to use their strong spines in their pectoral fins for movement on land and the slime on their skin surfaces to slide smoothly on wet grounds in the rainy season.

"Burrowing fish"

Some farmers and key informants said that some species of fish (members of the *Claridae* and *Notopteridae* families) are able to dig deep into the soft mud at the bottom and sides of ponds as well as streambeds and riverbeds. Others said that the fish do not dig in the mud, but rather they eat the remains of rotten tree roots that may surface at the bottom of these types of water bodies, creating deep narrow holes into the substratum in the space occupied by the dead plant root. These holes mostly go below the dry season water tables, and adult catfish (*Claridae*), cutlass fish (*Notopteridae*) and elephant fish (*Mormyridae*) were reported to stay in these holes over the dry season. They come out of the holes when the dry ponds, streambeds and riverbeds are flooded in the next rainy season. While in these holes during the dry season, the fish lay eggs, which are said to hatch at the onset of the rainy season. The adult fish that enter these fish holes breed to produce the small fish found in shallow water pools when flooding occurs during the rainy season. Some informants explained that fish fences across stream or river channels are aimed at preventing fish that reside in these holes from returning into the perennial rivers at the beginning and end of the rainy season.

An abandoned fish pond in Tonkolili.

Fish feed and spawn in floodplains during the flood season

Local fish farmers and fishers were knowledgable on the local "triangular" migrations of fish (Figure 5) (Sankoh 2009). The fishers said that during the rainy season the adult fish migrate from the main river basins into shallow floodplains to feed and spawn. The farmers further reported that adult tilapia stay around to guard their fertilized eggs and young fish during which time the receding flood water might leave them trapped in the deep pools or trap ponds. They reported that tilapia keep their eggs and young in their mouths for protection from predators (mouth breeding). These accounts of the feeding and reproductive behavior of fish are well documented in scientific literature (Adite, Winemiller and Fiogbe 2006; Richard Fleig 1993).

Attraction of fish into vegetation parks

The farmers were aware that upstream fish migration at the beginning of the rainy season is mainly for spawning reasons. Their account was that after the first rains catfish and cutlass fish make noises ("snores") when they are ready to spawn. At this time, farmers construct fish fences or barriers and traps or pots.

Farmers also reported that fish species with no scales are nocturnal and spawn at night during dark moons. This observation has also been reported in the open scientific literature (Herrero et al. 2005; Pohlmann, Grasso and Breithaupt 2001).

Farmebers or fishers use the knowledge of the spawning and feeding migrations of fish to decide when to construct fences and barriers to stop the adult and young fish from returning to the main river basins.

Some farmers also reported that the appearance of certain species of fish in their swamps signals the start of the period for transplanting swamp rice. These farmers believe that the fish are sensitive to external stimuli, but they were not sure what means the fish use to detect changes in environmental conditions. It has been reported in the scientific literature that fish use chemical receptors to detect aquatic environmental conditions (Akin, Winemiller and Gelwick 2003).

Knowledge of the predictability of food fish in "prime spots" is widespread in traditional fishing societies throughout the tropics, and the calendar devices and mental maps that enable fishers to track fish behavior according to lunar phases are among the most critical indicators of possible events in marine ethno-biology of fishing in coastal communities (Ruddle 1998). Maritime anthropology and ethno-ichthyology studies also illustrate the richness and resilience of artisanal fishing knowledge in many parts of the world (Silva 1997).

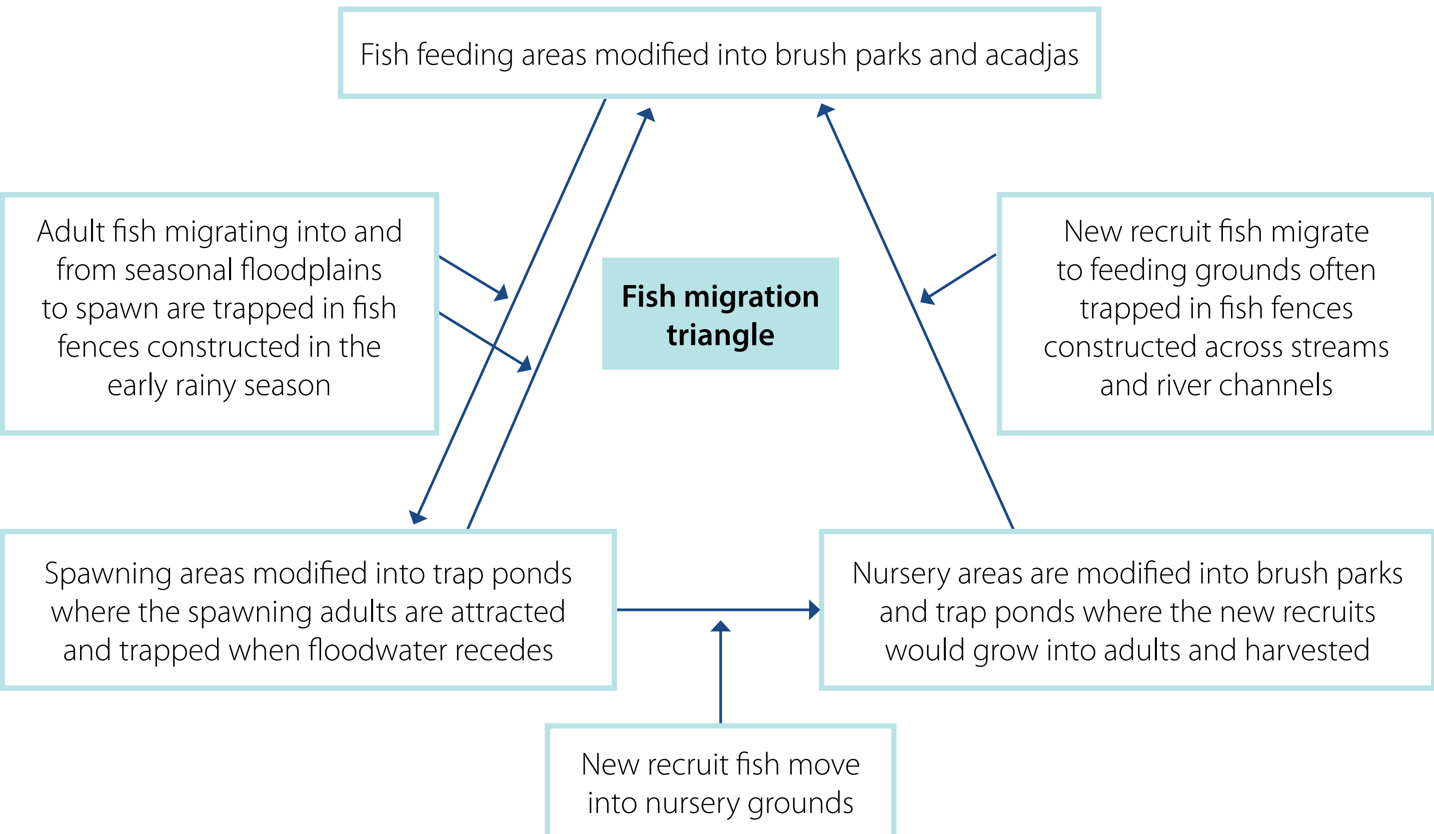


Figure 5. Fish migrations and exploitation in traditional fish farming in Sierra Leone (Sankoh 2009).

Use of local knowledge on feeding habits of fish for baiting traps

Detailed knowledge on fish feeds and feeding habits, learned by trial and error and passed on to successive generations, are gainfully used by farmers for designing, baiting and setting some fish traps and pots. The bait used is varied depending on the target species. Farmers in Tonkolili District used palm fruits in the rainy season and in deep water pots and traps, and they used earthworms and termites in shallow water at the beginning of the rains. Toward the end of the rainy season, and in mucky water, they used cassava tubers, apparently to enable the fish to see the white cassava bait. These materials were also used as fish feed in pond aquaculture in both Bombali and Tonkolili districts. Some fish farmers, particularly women, also reported that fish caught from the wild with the use of traps and scoop nets were sometimes used to stock their fishponds or put into wells for biological control of mosquitoes, which are vectors of malaria. They also clean wells by eating dirt or some other living organisms that accidentally fall into the wells.

Farmer experiences in fish production methods

Almost all fish farmers and fishers that participated in the FGDs and KIIs for this assessment had more than 5 years of experience in fish farming, and a few of them had more than 10. Very few farmers had less than 5 years of experience.

Only 114 ponds were constructed between 2012 and 2016, whereas 1094 ponds were constructed between 1987 and 2011 (Table 15).

Year	Number of ponds constructed
1980	10
1985	26
1989	4
1990	1
1991	7
1993	96
1994	6
1997	1
1998	2
1999	6
2000	16
2001	4
2002	171
2003	11
2004	32
2005	44
2006	56
2007	114
2008	46
2009	118
2010	215
2011	108
2012	81
2013	13
2014	2
2015	18
Total	1,208

Table 15. Construction dates for some ponds recorded in the aquaculture assessment.

There was a direct correlation between the age of an individual/number of years in fishing and fish farming with local knowledge on fish and fisheries. The names of fish in local languages were mostly known to the older people in the study areas. The younger people, who have either migrated to the cities or stayed in the village, had very little knowledge of fish or fisheries.

Local knowledge on management of fisheries resources

Secret societies (Box 1) reportedly implemented rules that have fish conservation values. The Poro Society in Tonkolili District was particularly said to maintain a useful requirement of keeping an isolated patch of primary forest through which a river flows. These forests and the rivers that flow through them are considered sacred. No farming or fishing activities could be carried out in these sacred places, and researchers in this assessment were not allowed to enter them or take photos. It was reported that members of the society use these sacred forests and rivers for initiation rituals.

The fact that these sacred forests and rivers are not open to the public for farming and fishing activities is a way of practicing maintenance through a buffer zone and implies that wildlife in such places could be protected from exploitation in some way. The wildlife conservation and protection value of the Poro Society was confirmed by the paramount chief of Konike Sanda, who reported that there were a lot of fish and wild animals, especially monkeys, that are never hunted or fished. These places are considered shrines accessible only to society members, so the research team refrained from asking too many questions about them.

These sacred places could also act as hatcheries and nurseries where fish could breed undisturbed and produce fingerlings.

Land tenure and pond ownership

Access to land and water resources

Secure access to land and water resources is a fundamental requirement for aquaculture, and the mechanisms that govern access and control of land and water need to be well understood by aquaculture planners and associated donor projects or investors. Where aquaculture requires the excavation of ponds, the labor and investment required are only justifiable where tenure of the land area involved is reasonably secure in the longterm to minimize risk. Rural people concerned with minimizing risk and maximizing returns on their labor, which is often the only resource at their disposal, will clearly think twice about excavating a pond and investing in aquaculture if there is a risk that the land on which the pond stands could be taken away from them (Townsley 1996).

A large number of actual and potential environmental problems and conflicts exist in Sierra Leone. At the heart of many conflicts is the leasing of large plots of land for mining and agricultural production that do not produce food for the local people and the sharing of benefits from the lease agreements. The conflicts also raise two questions: (1) whose values should be used? (2) who has access to the resource and how?

Over most of the country, land (the primary natural resource) is controlled through traditional systems, which have both advantages and disadvantages.

Land tenure systems

Land tenure in Sierra Leone is characterized by a dual system: "western" and "native." In Western Area (Figure 6), land is held under the English system of freehold interests, while the rest of the country is held in communal ownership under customary tenure. The result is a dichotomy between modernization and

Box 1

A secret society is a club or an organization whose activities, events and inner functioning are concealed from nonmenbers. The society may or may not attempt to conceal its existence. The exact qualificaions for labeling a group a secret society are disputed, but definitions generally rely on the degree to which the organization insists on secrecy and might involve the retention and transmission of secret knowledge, the denial of membership or knowledge of the group, the creation of personal bonds between members of the organization and the use of secret rites or rituals that solidify members of the group.

tradition. Although in Western Area, interest in land can be assigned with little difficulty, in the provinces the traditional authorities (paramount chiefs and other traditional rulers) are unwilling to sell land, because this will deprive future generations of the family from inheriting land from their parents.

Land tenure in Western Area

Some of the freed slaves who were resettled in Freetown, having lived in England before and experienced the English way of life and system of governance, were more inclined to live their lives like the British. As a result of this and other sociopolitical considerations, British concepts of tenure were introduced into the colony (Western Area).

Since the land on which the freed slaves were resettled was purchased in the name of the British monarch, the settlers were therefore tenants of the British Crown and the title passed on to them was the tenancy in a fee or freehold. After independence in 1961, the GoSL replaced the crown as the "landlord" of Western Area and the freehold system was allowed to continue (GoSL 2005). Figure 6 shows a map of Sierra Leone indicating where the freehold land tenure system operates in Western Area (Freetown and Environs) near the Atlantic Ocean and the rest of the country where a different land tenure system operates.

Land tenure in the provinces

In the provinces, land is communally held under customary tenure with minor differences among the various ethnic communities. Generally, land in rural Sierra Leone is considered a divine heritage, which the spirits of the departed ancestors expect to be preserved and handed down to future generations. It is entrusted to the living with a responsibility to ensure its preservation and subsequent assignment to future generations.

The paramount chief is regarded as the custodian of the land on behalf of the entire chiefdom, but the heads of the land-owning families are the ones who make decisions on the land. The administration of the community interest is vested in the head of the land-owning family who is aided by the Councils of Elders.

One important consequence of the fact that absolute interest in land is vested in the family is that it invests every member with an inherent right to the occupation and use of any part of the family land. When family members wish to cultivate any part of the family land, they have to get special permission from the family head, who would normally allocate land. In some societies, individuals have to pay money, locally referred to as *kola* ("handshake"), to the family head as acknowledgment of the land granted to him. The

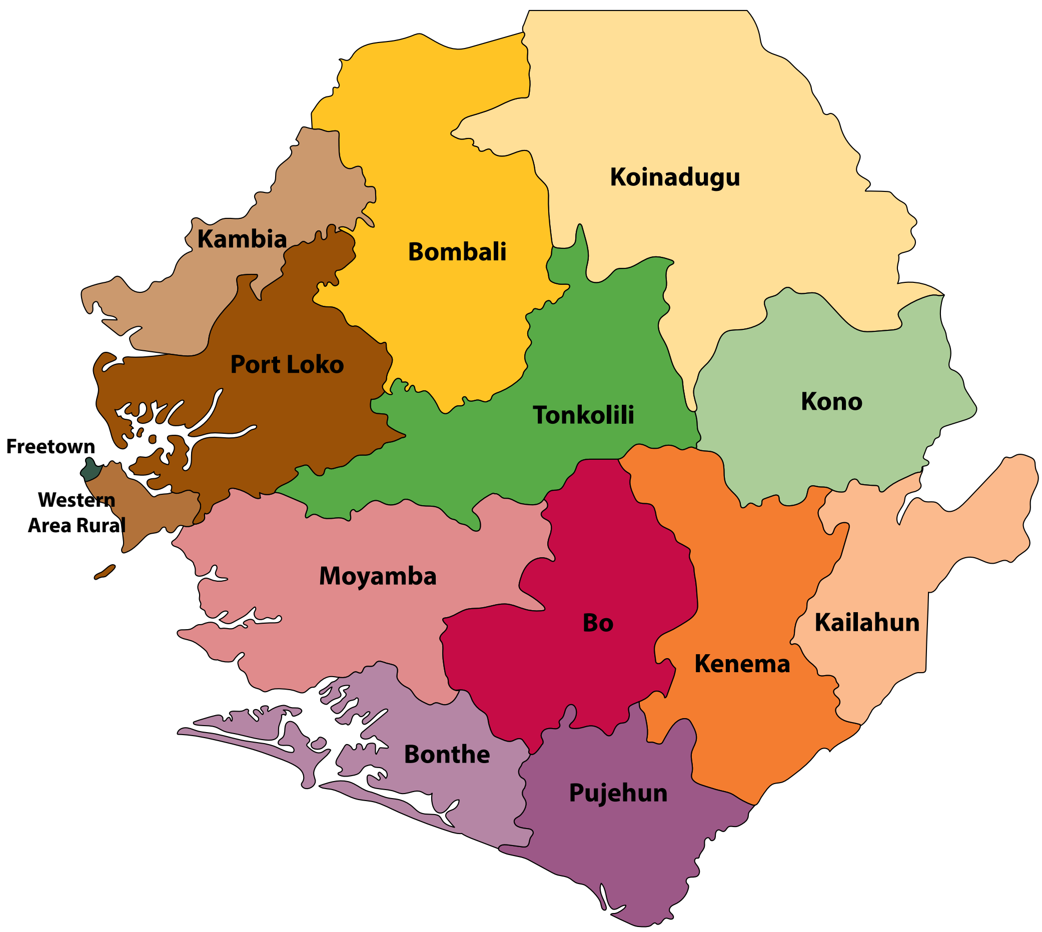


Figure 6. Areas of land tenures systems in Sierra Leone.

grant, however, does not confer ownership of the land but only the right to use it.

Access to land for women is far more difficult than for men regardless of their economic situation. In the provinces, a woman who wants to lease, borrow or hold land in trust often has to have a man guarantee her. By the existing cultural practices of property transfer, women hardly ever inherit landed property or houses from their fathers. When a woman's husband dies, either her adult sons or the brother of the deceased inherit his property, of which the wife is a part. This negatively affects women's potential involvement in digging and then running their own fishponds.

All chiefs and village headmen recorded in this study were willing to donate or allocate land to development agencies for use in community or group fishpond development projects. Some members of land-owning families could give land to moneylenders as collateral to ensure repayment. Although moneylenders hold a piece of land in trust, the family members are allowed to cultivate the land until the money is paid back. There are no limits to the date of repayment of such loans since the land has been given as collateral. Some families ended up losing the land completely because they could not pay back the loan, or they had continued adding the loan amount because of problems and financial difficulties. Female members of the family generally get married early and move into their husband's families where they get a temporary share or access to the husband's family land.

Conflicts in the uses of water resources

The current state of the use of water resources for domestic, industrial, agricultural and hydroelectric power generation purposes has not been fully studied. Work carried out in an effort to ensure an adequate supply of safe drinking water in the country has noted that water uses in mining, agriculture and industry and waste management can have deleterious effects on the environment or can interfere with other uses of the same resources for other purposes (Blinker 2006; Knight Piésold and Co. 2001; Sankoh 2001). These conflicting water uses are critical issues to consider in planning aquaculture development activities. At Makalie, where the government hatchery is located, water use for agricultural irrigation is competing with and affecting the use of the same resource for the government hatchery in the same area. The WorldFish project management in Sierra Leone has therefore established an alternative source of water for the hatchery.

Farming systems and management practices

Agricultural development strategies in most third world countries during and immediately after the colonial period have essentially been based on western technologies, with mixed success (den Biggelaar 1991). Farming Systems Research (FSR) was advanced as a way to increase the use of indigenous knowledge on farming to make new technologies more adaptable and appropriate to farming conditions, and this has enabled researchers to focus attention on people and their knowledge by increasing people's participation in problem identification and new technology validation (den Biggelaar 1991). In practice, though, FSR continues to be a top-down approach in which technologies continue to be developed (in most cases) in the exogenous knowledge system of the Western world.

Traditional aquaculture involves improving natural fish populations through knowledge and practices that can be complex and subtle, and they are usually based on community values and beliefs (FAO 1998). A practice is regarded as aquaculture if the fish stocked are accepted as owned by an individual or a group, called "growers," during the grow-out period until harvested (FAO 1998). Traditional aquaculture systems are commonly integrated with crops and livestock production, because on their own they are not productive enough to fully supply the dietary requirements of the farmers and their families (Edwards, Little and Yakupitiyage 1997). In Sierra Leone in general and in Tonkolili and Bombali districts in particular, earthen fishponds are mostly constructed in IVSs, where farmers also grow paddy rice. The same is true for Bo and Kenema. Kono is slightly different in that although the ponds there are found in IVSs, they are constructed in areas where diamonds have been mined before and not used for growing rice.

Aquaculture production systems in Sierra Leone can be classified into three broad categories.

1. Extensive: low level intervention, with limited feeding and fertilization, low capital investment and primitive management (e.g. trap ponds).
2. Semi-intensive: higher-level interventions, with higher capital investment in which the management regime ranges from an entirely extensive approach where nothing is added to ponds where fertilizer and supplementary feeds are administered (El-Gayar 2003).
3. Intensive: highest-level intervention, which is seldom practiced in Sierra Leone, with very high capital investment and high production levels and risks.

Origin of modern aquaculture practice in Sierra Leone

Aquatic production systems involving simple methods of improving fish production from natural water bodies arose independently in different parts of the world, particularly in floodplains along the lower courses of rivers, characterized by seasonal cycles of flooding and drought (ICLARM-GTZ 1991).

Oyster culture was tried in Sierra Leone in 1964 and 1973 in Freetown (Western Area of Sierra Leone) (Anon 1964a and 1964b; Anon 1965; Kamara 1976). "Modern" inland finfish farming was introduced in 1976 with the establishment of a government fish breeding station at Makali. In 1988, the Bo/Pujehun Rural Development Project set up demonstration and experimental fishponds in the town of Bo (Bangura and Cole 1987).

Traditional aquaculture systems

Overview of traditional farming systems

Traditional agricultural farming systems recorded in this study included crop rotation, shifting cultivation/ bush fallow and mixed cropping. Crop rotation is the successive cultivation of different crops in a specified order on the same plot of farmland. A typical rotation in the uplands involves rice in the first year, groundnuts in the second, millet in the third and cassava in the fourth. The farmland is then left to fallow for 5–10 years depending on availability of other plots of farmland. In shifting cultivation, a plot of land is cleared, burned and cultivated for a short period, after which it is allowed to revert to its natural vegetation (bush fallow). In mixed cropping or agro-forestry systems, two or more crops are raised in the same area at the same time. Many of the farms also include free-range livestock, poultry and traditional aquaculture. Agro-forestry involves integrating trees into farms and agricultural landscape. The trees could be for timber, medicine or what is generally referred to as "economic trees" (cocoa, coffee, oil palm, mangos, oranges and other fruit trees).

The above traditional methods of crop production are partly responsible for the large-scale abandonment of fishponds. When farmers move from one farmland to the next in shifting cultivation, they do not move with their fishponds, which they might have constructed in one farmland. The only time they may attend to or care for the fishponds is when they return to that farmland after the fallow period. Integrating fish farming with traditional crop farming is considered more productive. Such a system could use wastes from crop production as feed or a compost heap for fishponds, or fertile water with its wastes from ponds can be used to water/fertilize crops, such as vegetables.

Traditional fish farming methods recorded in the study could be divided into three broad categories in order of prevalence: trap ponds, fish fences and vegetation or brush parks (brush parks are fish aggregating devices, sometimes regarded as quasi-aquaculture systems). The most common methods recorded in Sankoh's (2009) study were trap ponds (>60%), fish fences and brush parks (~20%), fish pots and traps (<10%) and fish fences and traps (<5%). Fish fences and fish pots and traps by definition do not fall into aquaculture practices.[1] Instead, they are considered fishing gear.

Trap ponds

Origin and evolution of trap ponds in Sierra Leone

Key informants and farmers gave several stories and explanations about the origin and evolution of trap ponds in Sierra Leone. Some of the most logical stories included the following:

- ponds originally dug out in diamond and gold mining activities
- natural depressions and ponds dug by wild animals
- ponds originally dug as water wells.

Gold and diamond mining ponds

Diamonds were discovered in Sierra Leone in 1930 (William 2003). The alluvial diamonds were accessible to large numbers of people equipped with hand tools. In the early days of their discovery, crop farmers were reported to have picked diamonds while doing farming activities unrelated to mining (when they ploughed their crop lands or dug up plant roots used as traditional medicines).

Most of the holes used today as trap ponds were "diamond and gold pits" dug out in prospecting activities. The "pits" are flooded in the rainy season and they trap fish when the floodwater recedes.

Ponds started as natural depressions or were initially dug by wild animals

Some key informants explained that trap ponds or holes were originally natural depressions or holes dug out by wild animals, such as bush pigs, in their search for worms and water during the dry season. When flooded in the rainy season, these puddles attracted fish and trapped them when the floodwater receded.

Ponds initially dug as drinking wells

Rural farmers exploit underground water resources for domestic use by digging holes in their farmlands, especially at the edges of IVSs in the dry season. These farmers have developed a tradition of putting at least one catfish into the well to clean any "dirt" that may fall into the well ("biological water treatment"). When the catfish reach large sizes, they are removed and replaced with smaller fish, which are left to grow to large sizes, and the cycle is repeated. In some of the wells, fish get trapped during the flood season. The fish are then allowed to breed in these "safe" environments. Such wells are later modified into trap ponds and harvested every year.

Sources of water supply

Almost all of the fish farmers (96%) from Tonkolili and Bombali use perennial streams as water supply sources for their ponds, while only about 1% use underground sources. The remaining 3% use water from rivers and a combination of nonperennial streams and underground water. Water sources are the same for the other districts of Bo, Kono and Kenema where fish farming is done in mined out areas and in IVSs.

Distances from water supply sources

Most of the farms and ponds recorded in this assessment were within fewer than 100 m from perennial water supply sources, and only few farms, like the government hatchery, get their water supply from a dam that was over 1 km away. (WorldFish has since changed this, and the new water source is about 150 m away from the hatchery ponds.) Over 90% of fishponds documented in Tonkolili and Bombali districts were in IVSs with streams as the water supply. A good number of the streams dry up in the dry season, so many of the fishponds are seasonal.

Sources of fish stocked into ponds

About 30% of farmers simply dig the ponds and trap fish in them from the wild, whereas 27% get their fish from the government hatchery at Makali to stock their ponds. Another 35% of the ponds were stocked with fish from other farmers. Roughly 2% of the farmers stocked their fishponds with fish given to them freely by friends or relatives, and another 2% got free fingerlings from NGOs.

After stocking newly constructed ponds, most farmers reported that when they harvest their ponds they leave the small fish for restocking. Stocking fingerlings is only considered necessary at the start of fish farming. Although this is not a good practice, considering that the only government hatchery in the country was nonfunctional at the time, it is safe to say that this was their only practical solution for restocking harvested fishponds in the two districts, even though it is suspected to cause stunted growth in fish because the fingerlings used for restocking ponds may not be of good quality.

Managing fishponds

Feeding regimes

Over half of the fish farmers interviewed during the fishpond documentation in Tonkolili and Bombali districts said they never fed their fish, while the remaining farmers said they added rice bran/husks into their ponds as fish feed at irregular times during the dry season or fed their fish termites or peeled cassava (Plates 1–3). The feeding times were once

Plate 1. The son of a fish farmer adding rice bran and husks into his father's fishpond.

Plate 2. Breaking up a termite mound. No attempt is made to separate the termites out from the nest material. The whole lot is added.

Plate 3. Cassava peelings added to a pond and fenced in one corner (a crib). This can be used also to add other green matter to compost and lead to some form of pond fertilization.

a month (~30%), once a week (~15%) and two to three times a week (~5%). None of the farmers used commercial formulated feed because it is not available locally, and importing such feed would be too expensive for them.

Fish feed types

Most farmers who claimed they added feed into their fishponds used termites in the rainy season and rice bran or husks in the dry season. Small quantities of other feed items were also used. The frequency of supplementary feeding was dependent on the distance from the farmer's house to the ponds sites. Almost all farmers interviewed reported that they do not buy rice bran or husks. Instead, they get it by sweeping the compound after milling the rice produced by the farmers for household consumption

Manure

Few farmers said they used animal manure in their fishponds. Among those who did not use manure, most said they were not aware of using animal manure in fish farming. A few others said it was not good for the fish. Of the small number that used animal manure, most added it only once throughout the culture period. Farmers used cow, chicken, goat and pig manure to fertilize their ponds. Chicken manure was most common, followed by goat or sheep. Pig manure was the least common, because most of the farmers are Muslim, and according to the Islamic religion, raising or eating pork is *haram*, so it is rare to see people raising pigs in Tonkolili and Bombali districts.

Harvesting ponds

Trap ponds are harvested mostly using selective or partial harvesting methods. Many farmers remove fish as and when they need them, while a few farmers do complete harvests. Partial harvesting is often done without draining the ponds.

Harvesting gear

The most common fishing gear used in selective harvesting during the rainy season are hook and line and fish pots or traps (Plates 4 and 5), as well as scoop nets (Plates 6 and 7), because seine nets are either not available locally or where they are available they are too expensive for poor farmers. The equipment varies in size and shape depending on the depth of water in the ponds (Plates 10–13).

Fish species composition

Fish species harvested from trap ponds varied from place to place. They included tilapia, catfish and the banded jewelfish (*Hemichromis fasciatus*) as well as some frogs, with tilapia being the most common. Species composition depended on the stocking

Plate 4. Young boys using hooks and lines (partial harvesting).

Plate 5. A fish trap set in a pond. These can be baited with worms, frogs, fruit or cassava peelings.

Plate 6. A group of women working together using scoop nets woven from palm fiber to harvest fish from a trap pond. (Trap ponds cannot be drained.)

Plate 7. A pond drained in the dry season for complete harvesting.

method. Generally, catfish and cutlass fish tended to dominate trap ponds, whereas tilapia originally imported from the Ivory Coast dominated artificially stocked ponds.

Scientific principles of trap pond technology

The basic principles of trap ponds involve digging holes of varying sizes (25–500 m^2) in the floodplains. Some of these ponds developed out of abandoned diamond and gold mining pits (Plates 8–11). Fish breed in calm, shallow, nutrient-rich water, away from predators. Many freshwater species prefer nesting and laying eggs in depths less than 100 cm and in the presence of hard surfaces, such as vegetation, stones and pieces of wood (Munawar, Krishnamurthy and Pillai 1995; Ward and Samarakoon 1981). Spawning fish guard their eggs until they hatch and continue protecting and caring for their young for a couple weeks. Many species of the *Cichlidae* family keep the eggs and young fish in their mouths until they are independent. Parental care, including mouth breeding, has also been reported in the scientific literature for Cichlids, most notably tilapia (Owusu-Frimpong 1987; Ward and Samarakoon 1981; Welcomme 1975).

The rearing period for fish lasts 10–21 days during which the clutch passes through a range of developmental stages until they are free-swimming. This is followed by a transition phase during which fry are released for increasing lengths of time until they are independent. Maximum flooding periods last for about 3 weeks in Sierra Leone. Afterward, spawning adult fish and their young often become trapped in the ponds when the floodwater recedes. Sometimes, farmers construct fences around the ponds to prevent trapped fish from escaping. This technique has also been used in Benin, where rectangular trap ponds with their long axis running perpendicular to the river are dug out to increase the habitat available to the fish and ease their capture as floodwaters fall. After the annual flood has filled the ponds, the entrances are fenced off from the main river, and the pools are fished toward the end of the dry season (Welcomme 1979).

The concentration of suspended solids in the river was correlated with total ichthyoplankton density and related to species composition of juvenile characiform assemblages. These findings reinforce the hypothesis that nutrient-rich rivers and associated floodplains function as spawning and nursery grounds and suggest that they function as source habitats for these species in the Amazon Basin (A´lvaro and Araujo-Lima 2004).

The lifecycles of some species of freshwater fish synchronize with the flooding. Spawning for most of these species occurs during the rising water season,

Plate 8. A newly dug and still active diamond mining pit.

Plate 9. Diamond mining pits several years after being abandoned.

Plate 10. A newly dug gold mining pit.

Plate 11. A gold mining pit several years after mining activities.

between July and August, which coincides with an increase in food supply and areas of refuge for the young fish. Fish that go into semi-isolated, shallow, calm and vegetated pools of water in floodplains to feed and spawn become trapped after August when there are fewer rains (Kathirvel and Sultana 1995; Pillai et al. 2002; Goncalves et al. 2005; Junk 1985).

Different fish species migrate into and out of floodplains at different times and in particular groups (Williams 1971). *Clarias* spp., African butter catfish (*Schilbe mystus*), *Barbus* spp., and tilapia begin migrating earlier than other species, and in some tilapia species females tend to migrate earlier than males (University of Idaho 1971). Adult fish leave the floodplains as soon as there are indications of diminishing water levels (FAO/UN 1970), while juveniles leave at a later date (Agostinho and Zalewski 1995; Ward, Tockner and Schiemer 1999). An understanding of these fish migration patterns by local farmers would have been the basis for success in their traditional fish farming practices.

Fish fences

Fish fences are methods used by local people in Sierra Leone to harvest fish from the wild, usually for domestic consumption. These methods exploit seasonal changes in water levels and currents in floodplains and the migratory behavior of fish. The fences are generally constructed in small streams, and the types used depend on water depth, the general landscape of the floodplains and the species targeted (Welcomme 1975). The fences were regarded as traditional aquaculture in this assessment because the water area enclosed by the circular fences or immediately upstream of the linear fences and the fish in the enclosed water were regarded as belonging to the man that constructed the fence until it was removed or destroyed by water currents.

In some cases fences are fitted with two sets of traps: one that traps fish while trying to swim or migrate upstream, and the other fitted with entrances facing upstream. Fish that might try to swim or migrate downstream into open communal waters are flushed into the traps by high water currents. After each heavy rain, the trapped fish are removed. The traps, locally called *kayong*, are 1–3 m in length with an opening diameter of 30–50 cm and a closing diameter of 2–10 cm. Fish catches after heavy rains are often quite good. At the end of the rains, fish remaining upstream of the fence are harvested using scoop nets.

Types of fish fences

Two main types of fish fences were recorded in Tonkolili and Bombali districts: circular or rectangular (*ankunk*) and linear or curved (*ambank*)

The circular and rectangular fences are found in lakes, rivers and other relatively stagnant water bodies and are similar to fish cages, except that the fences are fixed on shallow lake beds or riverbeds and floodplains instead of floating or anchored by weights and the fish in the fences are not artificially stocked by the farmers. The enclosed areas of the fences vary from a few meters in rivers to over 1000 m^2 in lakes, lagoons and floodplains.

Straight or curved fences are constructed across smaller streams. There are several variations to these basic types with respect to the materials used in the construction and the types and sizes of traps fitted into the fences. The strength of the fence is a function of the prevailing water currents and depth of the floodwater. Shallow floodplains require simple fences constructed with some sticks and palm fronds. Fast flowing rivers and streams require stronger and more robust wooden fences. The sticks are sharpened and driven into the muddy bottoms of streams, rivers or floodplains. Other common forms of fences or barriers, mostly constructed by women, are made up of stones and mud, reeds and tree branches.

In coastal lagoons, enclosures are constructed about 30–60 m^2 in area and usually secured with vines and small openings facing the shores. At high tide, the enclosures are submerged. When the tide recedes, the fish are trapped inside and women use scoop nets to harvest them.

Materials used in fence construction

Materials used in fence construction include sticks, bamboo, palm fronds, raffia palm leaves, coconut palm fronds and bush ropes of different types, which are used to tie the sticks together. In a few cases, rocks and mud are used to create an embankment across the stream channel. The traps fitted into the fences are made from raffia palm, palm fronds and bamboo. In a few cases, branches are used to construct small circular trap fences.

Managing fish fences

Once a fence is constructed, the only management required is periodically removing debris swept downstream by the water currents and repairing the fence if the current breaks it. Sometimes, wild animals, such as monitor lizards, snakes and wildcats, will eat fish caught in the traps or destroy the traps fitted into the fences, necessitating replacement or repairs.

Harvesting fish fences

Throughout the life of a fence, particularly during the rainy season, fish are harvested after heavy rains using traps of different shapes and sizes. Fish that accumulate behind the fence are often flushed into the traps fitted into it, and farmers periodically remove the traps and empty the fish. At the peak of the dry season, when the water is almost dry, the water is drained off and the remaining fish collected, mostly by women. The fence is then repaired for the next rainy season.

Plate 12. Fences made of sticks, palm fronds and rocks to withstand currents.

Plate 13. Trap at base of the fence.

Plate 14. A strong fish fence across a stream with high currents in which sticks are used to strengthen the structure.

Plate 15. A small circular fence sometimes used as a fish cage.

Plate 16. A large circular fence in Lake Mabesi (only the tops of poles are visible during the rainy season).

Plate 17. Fish traps waiting to be placed in a fence.

Plate 18. Fish traps in place in a fish fence.

Plate 19. An alternative design of a fish trap sometimes used to collect fish as broodstock for fishponds.

Scientific principles of fish fencing

Fish fences constructed across rivers and streams act as barriers on the migratory routes of fish. The fish are concentrated in smaller areas near the fences, making them easier to catch. This ancient fishing method has evolved in Sierra Leone to the point that it now resembles fish farming, where farmers have control and ownership of the fish that have been concentrated. Open water bodies are communal property, so all community members can catch the fish without control. Meanwhile, streams and irrigation channels in swamplands are owned by individuals or families (Thomas 1996; Unruh and Turay 2006), and fish concentrated in these water bodies are by default owned by the farmers (Dorjahn and Fyfe 1962). Blocking the migratory routes of fish helps concentrate and keep them within farmer controlled areas (Hoggarth et al. 1999), which in turn limit access to the fish by other members of the community.

As practiced in Sierra Leone, using barriers to capture fish migrating within river channels has long been done in other parts of Africa (Whitehead 1958). Creating artificial impoundments that control water flow on floodplains is a means of preserving fish production in these areas (Phelines, Coke and Nicol 1973). Debris from upstream flushed down to the fence area helps create a more fertile and biologically productive system where fish grow rapidly. The fish are periodically harvested using the traps fitted into the fences and scoop nets used by women. The final harvest is undertaken in the dry season when the water level is low and easily drained completely.

Environmental impacts of fish fencing

Complete blockage of water courses for the purposes of trapping fish and preventing their seasonal migratory patterns interferes with the reproductive cycles of fish, restricts their access to preferred habitats and food resources, increases the chance of predation and disease, and reduces genetic flow between populations through population fragmentation.

Brush and vegetation parks

Brush and vegetation parks are forms of extensive fish production methods practiced in coastal lagoons and brackish waters in many parts of Africa. The brush parks are constructed in a variety of forms and sizes, but they basically consist of an inner core, or concentric circles, of densely packed tree branches or grasses surrounded by an outer, more substantial wooden framework, which is fished periodically, usually by encirclement (Welcomme and Kapetsky 1981).

Brush park fisheries offer a number of biological and economic advantages over other fishing or farming methods in tropical lagoons and estuaries. These advantages include a higher yield per unit area, use of low level technology and the potential to increase the biological productivity of the water bodies through nutrient input from the woody materials used to construct the brush parks. The disadvantages are the high labor requirement, theft, the limited areas where the system is physically possible (Welcomme and Kapetsky 1981), catching undersized fish and the use of mangrove vegetation in some countries.

Materials used in park construction

Vegetation parks are constructed by placing tree branches and their leaves or grasses in shallow water areas of floodplains to attract fish. In deeper floodwaters, palm fronds and grasses are used (Plates 20 and 21). After 1–2 months, the "park" is subsequently surrounded with netting prior to capturing the resident fish population. In simpler cases, floating vegetation and grasses are placed in the water to attract fish in search of food and refuge, and they are fished within a few days. This practice was recorded in Bombali District.

In more sophisticated cases, the floating vegetation is surrounded with palm fronds and sticks or branches, which are driven into the river or lake bottom (Plate 20) or an embankment of wood and mud (Plate 23). Branches are placed in fences or demarcated water bodies that are still connected with the main river or stream. These branches provide shelter and a feeding ground for the fish that tend to stay around these parks. When the water recedes in the dry season, the fish are trapped and then left to grow in the parks. They are removed at the peak of the dry season by draining the water completely and picking out the fish, or partially draining water and using scoop nets to remove the fish.

Managing brush parks

Harvesting brush parks

The fish that come into newly established habitat are continually harvested using selective traps, which catch and retain the adult fish, leaving the juveniles to grow. When the peak of ecological succession is reached, the fishers or fish farmers encircle the park with nets and catch most of the remaining fish in the park, which is then repaired by replacing rotten branches or grasses and poles. The process is then repeated. The branches placed in the water bodies provide shelter and feeding grounds for the fish that tend to stay around these parks (Silvano and Begossi 2005b). The branches thus work as fish aggregation devices.

Scientific principles behind brush parks

Brush parks (*acadjas*) function on the scientific principle of habitat enhancement, where natural habitat favored by certain species of fish is artificially replicated. Farmers may have learned that the parks offer fish shelter from predators and suitable places for breeding with an abundance of food in the form of a periphyton "mat" on the surfaces of branches and the bottom fauna enriched by decaying wood (van Dam and Verdegem 2001; Welcomme 2002).

The natural processes within the brush or vegetation parks are essentially secondary ecological succession processes. These involve colonization of the created artificial habitats by a series of communities of organisms, from the micro to macro level, with complex trophic interactions that peak with the prey-predator trophic interactions (Dempster, Baird and Beveridge, 1995; Dempster, Beveridge and Baird 1993).

The different stages of ecological succession in the parks include settlement of macroalgae on the poles then the periphyton. These are followed by invertebrate species such as freshwater gastropod snails (*Physella spelunca*, *P. squalida* and *P. boucardi*) and prawns (*Macrobrachium* and *Neocaridina* spp.). These colonizers feed on the algae and detritus from the decaying leaves. The detritus feeders are soon followed by the tilapia and then carnivorous fish like the Reticulate knifefish (*Notopterus afer*), catfish species (*Clarias* spp) and African pike characin (*Hepsetus odoe*).

Plate 20. Palm fronds and branches used to demarcate a brush park.

Plate 21. A brush park in a floodplain.

Plate 22. Sticks used to demarcate a brush park.

Plate 23. Sticks and mud used to demarcate a brush park.

Plate 24. A trap used to harvest fish in deep water brush parks.

Plate 25. A gill net used in harvesting brush parks.

In these systems, the heterotrophic organisms (bacteria, protozoa and other invertebrates) decompose organic matter that the fish can use. A large part of the microbial production in the system is based on algal detritus (Schroeder 1978; Schroeder et al. 1990), and the phytoplankton produced in the system is decomposed on the bottom of the parks and contributes to the accumulation of nutrients in the sediment.

Fish species, like tilapia, that feed on phytoplankton and macroalgae and bottom detritus feeders, such as invertebrates like snails and prawns, will invade the new habitat. Catfish and cutlass fish are next to invade the brush parks in the sequence of secondary succession (Dempster, Baird and Beveridge 1995; Dempster, Beveridge and Baird 1993).

Fish yields and twig density in brush parks and the number of days since their installation were investigated in Sri Lanka and shown to have a strong relationship (Solarin and Udolisa 1993; Welcomme and Kapetsky 1981).

"Modern" fishponds

"Modern" fishponds were introduced in Sierra Leone in 1976, but during this time there were already trap ponds or fish holes in many parts of the country where fish were self-recruited. To local people who tried to adopt modern fishpond technologies, the difference between their trap ponds and the newly introduced fishponds was that the fish had to be physically stocked into the new ponds and cared for, fed and, in some cases, treated as domestic animals.

This new regime of caring for fish was totally new and time consuming. On top of this, the idea of stocking a single fish species (tilapia) was not readily acceptable, because local people were used to having ponds that self-recruited different species. The fish were neither fed nor cared for, though the women always caught some of them for home consumption.

Despite the unfamiliar nature of the new fish farming method, rural farmers were always attracted in the early days of the introduction for the following reasons:

- Foreigners were involved (Peace Corps volunteers from the US).
- Free extension services and some free basic inputs were provided.
- The technologies were easy to integrate into the IVS development for swamp rice cultivation.
- Once fish were put in a farmer's newly constructed fishpond, it was not necessary for the farmer to care for it because there was always some fish in the pond, whether the farmer cared for them or not.

As a result, farmers were always willing to construct fishponds, when they had an opportunity to do so, and would leave the fish in the ponds to fend for themselves. As expected, the yield and productivity of the modern ponds were low.

Ownership categories and management of fishponds

Individual or family ownership

In Tonkolili and Bombali districts, 87% of the ponds recorded were owned by individual farmers or families, and only 13% were owned by communities or organized groups (Table 11). The FAO aquaculture baseline survey did not record pond ownership for the districts of Bo, Kenema and Kono, so trends in ownership could not be compared. In 2015, at the time of this study, only 12% were operational of the more than 2000 fishponds documented in this assessment (Table 11). This was significantly lower than the 2009 study, which found that 50.2% of recorded fishponds were in active production. Almost all of the more than 1000 fishponds constructed before the year 2000 have been abandoned by their owners for various reasons. Similarly, the majority of the fishponds constructed between 2000 and 2010 have all been abandoned, suggesting that fish farmers in Tonkolili and Bombali maintain their fishponds for five years or fewer. In this assessment, 107 of the 251 active fishponds recorded were constructed between 2010 and 2015, whereas only 92 constructed between 2000 and 2009 were still in active production. Most of the operational fishponds (92%) were recorded in Konike Barina and Konike Sanda, which are the closest chiefdoms to the Makali fish hatchery and extension services center for fish farming.

Communities and organized groups ownership

Ponds owned by communities and groups (mosques/schools/associations) were motivated by support from either the government or NGOs, whereas fishponds owned by institutions like secondary schools and technical or vocational institutes were motivated by practical teaching purposes.

In total, 369 fishponds were supported by NGOs and other development agencies. Support for aquaculture started as far back as 1985 by the American Peace Corps, but most support was given to farmers between 2000 and 2010. However, of the 369 fishponds supported by development projects and NGOs, only seven were operational at the time of this assessment (Table 10). The study found that 85% of fishponds were owned by individuals or families and only 15% by organized groups or communities (Table 11). The results also showed that most of the ponds were constructed and stocked for production between May and December.

Some farmers come together and construct fishponds for communal purposes when land is limited or whenever it is expedient to establish such community ponds through support from NGOs. Almost all the ponds owned by community or organized groups were motivated by support from development partners and NGOs.

Individual adult men who own fishponds most often only contributed labor in the fishpond construction work. The general management work of the fishponds owned by individuals or families and households was mostly carried out by women and children. Fishponds owned by associations (e.g. the Fish Farmers Association) were initiatives of groups of individuals who may have shared or common interests, such as the labor clubs discussed earlier in this report.

Members of the associations were headed by mostly the village elites. Most often the initial motive for organizing an association was not for fish farming. Fish farming was incorporated into the primary activities of the associations to attract available support from NGOs, and once that was achieved they often had less time for sustaining fishpond production.

Ponds characteristics and distribution by chiefdom

Half of the fishponds recorded in Tonkolili District were in Konike Barina, while 44% were in Konike Sanda. Only 1.6% were in Gbonkolenken, 1.4% in Tane, 1% in Kolifa Rowala and 1% in Gbendebu, which is in Bombali District. The rest of the chiefdoms had less than 1% each. There were 2087 ponds among the 1113 farms and fish farmers in the study. Over half of the farms had only one fishpond while one-third had two (Table 16).

The overall picture seems to be that, with or without support from development partners or NGOs, farmers in Tonkolili District are slowly adopting new fish farming technologies but are still lethargic or have no time for the difficult process of managing a fishpond to maximize returns on labor. A lot more training and demonstrations might be required to convince farmers that fish farming could be very profitable if given adequate time and attention. Extension services and training as well as the provision of quality fish seed and feed are some of the primary considerations needed for this to happen as outlined by the farmers themselves (Section 3.12.3.2 and Table 19).

Number of farms	Number of ponds on each farm	Total number of ponds on farms	Average size (m^2)
554	1	554	341.2
354	2	708	359.6
102	3	306	449.3
64	4	256	372.1
19	5	95	494.7
10	6	60	391.1
3	7	21	226.1
2	8	16	400
1	9	9	2,000
1	11	11	150
1	13	13	200.2
1	16	16	500
1	22	22	400

Table 16. Number of ponds owned by farmers.

Management and maintenance, roles and responsibilities

Gender and labor roles in households and families

Gender roles are fairly distinct. Work regarded as physically demanding and technical, such as clearing the fields, digging or plowing (including mining and pond construction), climbing trees to harvest fruit or tap palm wine, fishing in deep open waters, is mainly done by men and boys. Women were most active in planting, harvesting, weeding, wood gathering, food processing and cooking, marketing farm produce, childcare and general housekeeping (Table 17).

Children, especially girls, help their mothers, and the boys help their fathers in their different roles and farming activities. Male children are also tasked with scaring birds and monkeys from the farms and checking traps set by their parents. Fishponds recorded in Tonkolili and Bombali districts were generally poorly managed. Out of the 2087 fishponds documented in the study, only 251 were in active fish production. The remaining 1836 were either producing intermittently or abandoned entirely (Table 18).

Task type	Adult male members	Adult female members	Male children	Female children
Land clearing/preparation	√√√√√	√	√√√	√
Wood gathering after burning cleared field	√	√√√√	√√√	√√
Plowing	√√√√√	√	√√√	√
Transplanting/sowing	√√√	√√√	√√	√√
Weeding	√	√√√√√	√√	√√
Fencing and setting traps	√√√√√		√√√√	√
Bird scaring	√	√	√√√√√√√	√
Harvesting	√√√	√√√√	√√	√√
Processing and marketing	√	√√√√√	√	√√√
Clearing land for pond construction and demarcation of pond dike boundaries	√√√√√√	√	√√	√
Pond construction	√√√√√√	√	√√	√
Stocking ponds with fish from the wild	√	√√√√	√	√√√√
Gathering fish feed and feeding	√	√√√√	√	√√√√
Harvesting fish	√	√√√√	√√	√√√
Processing and marketing fish	√	√√√√	√	√√√√
Cooking and general housekeeping		√√√√√√		√√√√
Childcare		√√√√√√√√		√√

Table 17. General household production and economic activities and gender roles.

District	Chiefdom	Average pond size (m^2)	Inactive	Operational	Total
Bombali	Gbendebu Ngahun	363.64	22		22
	Pakiemasabong	334.00	4	2	6
	Safrokor Limba	262.50	2		2
Tonkolili	Gbonkolenken	448.81	21	12	33
	Kafe Simra	63.38	1	2	3
	Kolifa Mabang	600.00	1		1
	Kolifa Rowala	363.81	19	2	21
	Konike Barina	256.91	941	103	1,044
	Konike Sanda	321.25	794	128	922
	Tane	176.42	29		29
	Yoni	220.44	2	2	4
Total		**289.50**	**1,836**	**251**	**2,087**

Table 18. Operational status of fishponds in Tonkolili and Bombali districts.

Farmers' perception of fish farming in ponds and reasons for abandoning ponds

Overall, farmers were positive about fish farming, but there were a number of reported problems (Table 19), particularly the lack of inputs and support services available. Some farmers pointed out that predators in the ponds were also a problem. Others thought that modern fishponds were an expensive system for producing fish.

Lack of inputs

Fertilizers, feed and even basic tools and implements, such as shovels and wheelbarrows and gill nets, are not produced in Sierra Leone, and the government had to subsidize limited quantities of inorganic fertilizers imported into the country for agricultural development projects under different IADPs so that local people would to be able to buy them. Farmers are therefore dependent on basic tools (e.g. cutlasses, hoes, scoop nets and fish traps) locally made by village blacksmiths and weavers and a lot of materials from the natural environment, such as plant materials (e.g. sticks, bamboo, raffia, ropes, leaves and grasses), rocks and mud.

Predators

Local farmers identified birds (locally called "water ducks"), banned jewelfish (a carnivorous fish that eats the eggs and young of more important fish in ponds), water monitor lizards (*Varanus salvator*), water snakes and frogs (*Lithobates palustris*) as common predators, especially in ponds. Leeches were identified as parasites in the production systems, killing fish and making work unpleasant for people.

Local farmers were aware that brushing areas around the production sites would keep away water snakes and monitor lizards, and water ducks could be effectively controlled by having children scaring them away or installing scarecrows. The predator fish jewelfish could effectively be excluded by fishing them out with a hook and line and screening the inlet and outlet bamboo or PVC pipes once the flood season is over.

Cost

The reported high cost of aquaculture production is believed to be related to modern methods. Farmers are most likely required to use imported inputs and technologies, which are very expensive, at least to poor rural farmers. Farmers who produced fish for home consumption found it difficult to justify investing in expensive farm implements for use in such production systems.

Lack of technical knowledge

The MFMR in Sierra Leone is a relatively a small ministry. It was under the MANR from 1961 to 1992 until it was given full ministry status in 1992, when the military government seized power and set up the National Provisional Ruling Council. During these early days of the MFMR, very few technical personnel were moved from its parent ministry into the newly created Fisheries and Marine Resources Ministry. The civil war had not allowed the MFMR to recruit, train and deploy extension agents into rural areas, apart from the handful recruited in the aquaculture trials in the Bo-Pujehun Rural Development Project and the Makali government hatchery. Most extension services for fish farmers were therefore provided by agricultural extension officers who could help them if they needed advice on fish farming. Most farmers interviewed in this assessment preferred consulting other farmers because there were no extension agents around.

Problems	Responses	
	Number	Percentage
Inputs are not available locally	141	30.3
Natural predators	136	29.2
Expensive production method	43	9.2
Lack of technical know-how	39	8.4
Poor/stunted growth of cultured fish	38	8.2
Labor intensive and tedious	29	6.2
Poachers	20	4.3
Floods sometimes flush fish away	11	2.4
High mortality of fish during transport and in ponds	8	1.7
Water source is not perennial	1	0.2
Total	**466**	**100**

Note: Respondents were permitted multiple responses so totals are greater than number of respondents.

Table 19. Farmer's perception of fish farming problems (Sankoh 2009).

Poor growth

Farmers who stocked their ponds with tilapia reported that the fish did not grow well. However, additional questions revealed that the farmers were not feeding the fish or they had stocked their ponds with poor quality fish from their own ponds or others owned by friends and relatives.

Labor intensiveness

A few farmers said that walking to and from the pond sites to feed their fish was tedious and that keeping thieves and predators away makes fish farming even more demanding. Since these farmers are used to harvesting fish from trap ponds, for which they spend nothing to feed or care for the fish, they will always be reluctant to pay for inputs. Even if such inputs are made locally available, they would similarly say they are too expensive. Only commercial fish farmers would be able to invest in large-scale fish farming for Sierra Leone to make a significant contribution to the global fish supply from aquaculture.

Although rural farmers were aware that fish can reach large sizes in ponds, they might not know that, given care and proper feeding, fish in ponds can reach market sizes faster than they do in trap ponds. Therefore, intensive training on all aspects of fishpond farming, including fishpond site selection, pond construction, management and general fish farm business management practices, are key to the success of fish farming in Sierra Leone.

Sharing benefits from fish harvests

Regarding who gets the fish or money from the sale of fish from fishponds, there are variations on who benefits and how much, depending on the different pond ownership regimes in the study areas.

Community owned ponds

Ponds owned by communities are often harvested once or twice a year. After harvesting, some of the fish are given to the chief and other respectable members of the village (chief imam, pastor, etc.). The rest are either sold and the money shared among the members of the community, or the fish are shared by households, regardless of the number of members in them. Sometimes, large households become dissatisfied with this and might decide not to participate in future work on the community pond. This might be responsible for the high rate of abandonment among community ponds.

Individual or family owned ponds

Fish harvested from individual or family owned ponds are normally eaten in the household. Only a small quantity is sold by most farmers. Many said they sometimes do partial or selective harvesting when they need fish to cook for the household. During the final harvest, after 3–6 months, some of the harvested fish are given to friends and relatives, who help with the fish farm work, and important members of the community.

Group or association and institutional ownership

Many of the ponds owned by associations reported poor yields and productivity, so there were limited benefits to share among their members. This is probably a result of poor participation in the management and maintenance of the ponds. This study only recorded one pond owned by a school and one by a mosque. However, Sankoh (2009) found that ponds owned by schools and other educational institutions were mostly used for teaching or practical demonstration. The harvested fish were often all sold and the money used to buy tools. Sometimes, the fish were shared among the school administrators and the agriculture teacher, while the students gained technical knowledge from practical exposure.

Production

Fish production levels were not assessed in this survey. However, Sankoh (2015) carried out an economic analysis of fishpond farming in Sierra Leone in which he recorded a mean annual production of 96 kg of fish per farmer out of a sample of 200 farmers. Plates 26–29 give an idea of the types of fish harvested in fishponds and vegetation parks either in partial or complete harvests (Sankoh 2009).

Common sizes of fish harvested

The common size ranges of fish harvested by farmers are given in Table 20.

Sizes of fish harvested (g)	**Responses**	
	Number of respondents	**Percentage**
100–499	93	26.1
50–99	144	40.3
Up to 49	51	14.3
Fingerlings	69	19.3
Total	**357**	**100**

Table 20. Common sizes of fish harvested by farmers (Sankoh 2009).

Fish storage, processing and marketing

Because fish is perishable, it needs to be processed once it is harvested or disposed of quickly as fresh product to prevent spoilage. The quantities of fish harvested at a time and the distance from the fish farm to the village or market, to a large extent, determine handling or processing or storage methods. Similarly, the marketing potential of the fish produced depends on the species and sizes and the time of the year the fish are harvested.

Fish harvested or caught in the wild are sold by the road side. The majority of farmers store their fish in baskets, bowls or buckets after harvesting. A few people keep the small fish in holding ponds by the side of the main pond and put the small fish back into the main pond after a complete harvest. Plates 30–33 show the different fish processing methods in the study areas.

Plate 26. Mixed species from a partially harvested trap pond.

Plate 27. Mixed species from a partial harvest.

Plate 28. In stocked ponds, the catch tends to be more uniform.

Plate 29. In brush parks, the catch tends to be more uniform and dominated by tilapia.

Plate 30. Catfish caught by hook and line during a partial harvest.

Plate 31. Fish gutted and split before smoking.

Plate 32. Smoked fish for sale in a market.

Plate 33. Fried fish for sale in a market

Smoking is the most common fish processing method. Nearly 45% of harvest fish are smoked, 37% are sold fresh, 15% fried and 3% dried (Sankoh 2009).

Market outlets for farmed fish

Most of the farmers sold harvested fish within their immediate community (Table 21). Fish produced from the ponds were mostly sold or shared at the pond site or in the village where the farmers lived. Many farmers interviewed agreed that they do not produce enough fish to sell, so they either eat all the fish produced or sell a fraction to meet other family responsibilities, such as school fees and medical bills.

Fish marketed	Responses	
	Number	Percentage
All in the village	76	31.9
Some in the village	60	25.2
Some in weekly/urban markets	40	16.8
All on the farm	22	9.2
Some on the farm	20	8.4
All in weekly/urban markets	12	5.0
Some in neighboring villages	6	2.5
All in neighboring villages	2	0.8
Total	**238**	**100**

Table 21. Market outlets for farmed fish (Sankoh 2009).

Species

Almost 98% of the ponds were stocked with tilapia. Only 0.7% were stocked with catfish and 0.34% with mixed species (mostly from the wild or self-recruited as in trap ponds), while 1.34% of the ponds were either abandoned, not in active production or did not have any fish. Exactly 1.4% of the ponds recorded in the assessment were either abandoned or the pond owner was not available to give information on the species stocked when the ponds were in active production.

Input supplies and support services

Seed supply

Only one government hatchery provided tilapia fingerlings. This hatchery was only partially functional at the time of the assessment, because all the ponds were dry and the technicians in charge reported they only produced fingerlings during the rainy season. A total of 555 ponds benefitted from the hatchery's supply of fish fingerlings or broodstock (Table 22). The rest were either stocked with fish from other farmers in the neighborhoods (763) or from the wild (54). A good number of the farmers did not provide information on the sources of fingerlings stocked into their ponds (692). The government hatchery imported its first fingerlings/broodstock from Ivory Coast (16 ponds). At the time of this assessment, WorldFish had refurbished the hatchery at Makali for the production and supply of tilapia and catfish fingerlings. This is seen as a golden opportunity for fish farmers in Tonkolili District.

Feed supply

There is no local commercially formulated fish feed supply source in Sierra Leone. All farmers interviewed used different local ingredients to feed their fish, or they simply left their fish in the ponds to fend for themselves. Local ingredients included rice bran, cassava, vegetable scraps/leaves, termites and palm kernels. Almost all ponds were fitted with a compost crib to fertilize the ponds.

During the assessment, there was an increase in the livestock population in the district and many ABCs where agricultural produce was processed. Key among the produce were the rice mills and the cassava craters. Waste from processing this produce is reportedly very useful feed for fish (Plate 34).

Plate 34. Bags of rice husk/bran produce in all ABCs in Tonkolili and Bombali districts.

Extension services

The only places where fisheries assistants or technicians were present and reported to serve as extension agents were in Makali, where the government hatchery is, and in the Bo experimental station, where an agriculture assistant was present and provided limited extension services.

Over 80% of the farmers recorded in Tonkolili and Bombali districts depend on older farmers in their areas for technical advice on fish farming. A few farmers in Manasi and Makali had benefitted from training conducted by the Peace Corps volunteers in the 1980s, and these older and more knowledgable farmers are reportedly very useful in advising younger farmers in the districts on fish farming.

Donor support for aquaculture

NGOs and other development partners or the government supported 369 ponds in one form or another. The most common form of support was food or tools for work, with very few benefitting from knowledge transfer or training. It is believed that if the support had concentrated on training and knowledge transfer, fish farming practices would have been better sustained. Providing food or tools for farmers to construct ponds was not sustainable because most farmers reported that the amount of food they received from constructing fishponds was more valuable than the fish they produced in the first year of fish farming. The farmers might have opted to dig fishponds only for the expected food supply, after which they simply abandoned the ponds.

District	Chiefdom	Source of fingerlings	Number of ponds that benefitted from source	Average number of fingerlings required	Average number of fingerlings stocked	Average area of pond (m²)
Bombali	Paki Masabong	Middlemen	5	400	400	352
		NGO	1	400	400	336
	Safroko Limba	Wild	2	No data	No data	525 15,000
	Gbendembu Nguahun	Government hatchery	22	No data	No data	363.6
Tonkolili	Konike Barina	Government hatchery	493	513/pond	344/pond	236.5
		Middlemen	103	485 /pond	233/pond	264
		Gift from other farmer	18	50/pond	50/pond	164
		Ivory Coast	16	1,500/pond	500	486
		Wild	10	210/pond	110	198.24
		No data	404	No data	No data	556.03
	Konike Sanda	Middlemen	610	206/pond	266	442
		Government hatchery	17	491/pond	139	323.5
		NGO	4	734/pond	240/pond	259.2
		Gift	18	85/pond	85/pond	222.1
		Wild	39	174/pond	139/pond	158.3
		No data	234	725/pond	332/pond	331.8
	Tane	Middlemen	3	44	44	86.3
		Government hatchery	6	233	200	326.7
		No data	20	No data	No data	185.4
	Gbonkolenken	Middlemen	6	720	720	448.05
		Government hatchery	4	600	600	597.55
		Wild	3	No data	No data	379.1
		No data	12	No data	No data	462.5
		Awaiting stocking	8	No data	No data	368
	Kolifa Rowala	Middlemen	1	No data	No data	390
		Government hatchery	12	272	227	369.2
		No data	8	No data	No data	607.1
	Kafe Simera	Government hatchery	1	50/pond	50/pond	47.2
		No data	2	50	50	69.0
	Kolifa Mabang	Wild	1	No data	No data	600
	Tane	Middlemen	3	44	44	80.2
		No data	20	No data	No data	191.3
	Yoni	No data	4	No data	No data	220.96

Table 22. Numbers of fishponds that benefitted from different sources of fish seed in Bombali and Tonkolili districts.

Economic assessment of fish farming results

Projected average costs and returns from 10 years of continuous fish production are given in Table 23.

Profitability of fish farming in fishponds

Profitability ratios used in a fish farm investment include gross profit margin, cost-benefit ratio and payback period. Profitability in fish farming is a measure of the farmers' net returns from their fishponds. Gross profit margin is given by

$$GPM = \frac{NI}{GI} \times 100$$

Where *GPM* = gross profit margin
NI = net income
GI = gross income

Gross profit margin serves as the source for paying additional expenses and future savings.

Mean annual net income for farmers by farm size and region are given in Table 23. The profits, defined as gross income minus cost of production, were SLL 111,856.15 (USD 18.64) for small farms, SLL 203,341.48 (USD 33.89) for medium farms and SLL 236,515.69 (USD 39.42) for large farms, for an average of SLL 142,273.34 (USD 23.71).

Cost-benefit ratio

The cost-benefit ratios by farm size were 2.44 for small farms, 2.56 for medium farms and 1.82 for large farms, for an average of 2.34 for all 200 farms.

Payback period

The payback period was calculated assuming that the farmers borrowed the money used to invest on fish farming for different categories of farm sizes.

Payback periods for interest-free loans were 4.10 years for small farms, 3.90 years for medium farms and 5.49 years for large farms, for an average of 4.27 years for all farms. Payback periods for loans at a 20% interest rate were 6.62 years for small farms, 6.22 years for medium farms and 9.57 years for large farms, for an average of 6.94 years for all farms.

Projected cost and returns	Small farms (n = 138, P = 276.81 ± 0.06 m²)	Medium farms (n = 47, P = 620.53 ± 16.42 m²)	Large farms (n = 15, P = 1903.70 ± 230.22 m²)	All farms (n = 200, = 479.60 ± 35.68 m²)
Total 1st year production cost	254,956.8 ± 15,531.74	379,177 ± 19041.79	886,293.7 ± 125,675.8	331,171.5 ±19,809.29
Running cost in 2nd year	95,127.10 ± 3,092.54	167,366.33 ± 8,520.89	363,825.03 ± 34,470.24	133,031.60 ± 6,561.53
10 year discounted production cost	775,953.6 ± 32,951.82	1,300,264 ± 68,923.06	2,880,204 ± 328,948	1,060,664 ± 57,391.94
Mean annual production cost (SLL/m²/year)	280.32 ± 11.90	209.54 ± 11.11	151.2951 ± 17.28	221.16 ± 11.97
1st year mean gross income	361,846 ± 21,825.15	645,948.7 ± 70,993.81	1,000,001 ± 162,839.8	475,820 ± 29,696.56
10 year total discounted gross income	1,894,512 ± 2,511.3	3,333,691 ± 352,382.9	5,245,381 ± 41,832.5	2,483,382 ± 137,674.2
Net annual profit (SLL/year)	111,855.8 ± 5,955.95	203,342.6 ± 8,345.99	236,517.7 ± 41,288.45	142,271.8 ± 8,028.22
Gross income (SLL/m²/year)	684.41 ± 33.42	537.23 ± 56.79	275.5361 ± 38.97	517.80 ± 28.71
Net profit (SLL/m²/year)	404.09 ± 21.52	327.69 ± 45.68	124.24 ± 21.69	296.65 ± 16.74
Gross profit margin	59.04	61.00	45.09	57.29
Cost-benefit ratio	2.44	2.56	1.82	2.34
Payback period (loans without interest)	4.10	3.90	5.49	4.27
Payback period (loans with 20% interest)	6.62	6.22	9.57	6.94

Table 23. Projected average costs and returns from 10 years of continuous fish production at the same level by farm size. P = mean farm/pond size in m²; n = number of respondents; all values in SLL).

Annual net incomes from fish farming

Annual net incomes from fish farming were increased progressively by expansion in farm size, but the net income per unit area of pond per year decreased with expansion. This is because increased pond sizes required an increase in labor without a proportional increase in yield, causing diminishing returns on labor.

The decrease in the net annual income per unit surface area could also be due to the complex relationship between supply and demand for fish in the village setting. Large farms might have been producing more fish than the village market can absorb at particular times of the year. This could then have forced fish farmers to sell their fish at lower than average prices, which would have decreased their total incomes.

Alternatively, farmers may have not applied standard stocking densities. Large ponds might have been understocked, so the additional expenditure of constructing them could not be recovered because the number of fish stocked into them was fewer than optimal.

Generally, the annual net profit that farmers accrued appeared to be too small to justify fish farming as the only occupation for a farmer. However, unpaid family labor was costed in the analysis, so fish farming is making a useful contribution to household income. If the integration of fish and rice, which was very common in Tonkolili and Bombali, is considered, then total returns from both the rice and fish could be profitable for the poor farmers in the districts.

Costs of labor and farm inputs

Sankoh (2009) recorded that the most important cost item in pond fish farming systems in rural Sierra Leone was labor, accounting for about 70% of the total production cost. The ACP Fish II study estimated that for a 2000 m^2 dam pond, the investment cost was USD 490 of which USD 260 was labor and USD 230 was for tools and construction materials. Sankoh (2009) reported that in the ACP study, after the initial investment costs, farmers spent very little on operational costs because most of the pond maintenance operations were carried out using family labor, and fish eaten by the family and given away to family members and friends accounted for about 10% of the value of the harvested fish (estimated at USD 25/year for a 2000 m^2 pond).

Cost of renting land

Land leasing was not a common practice in rural Sierra Leone, so Sankoh (2009) estimated the cost of land using a proxy value. The opportunity cost of using land for fish farming was considered as the forgone use value of the same plot of land. This was estimated as the value of crops (rice, vegetables and root tubers) that could have been grown where the ponds were. Based on the proxy value of land as leased, a 500 m^2 pond was estimated to cost USD 327/ha/year. This cost is considered to be an overestimate because family land is not paid for, and if the land used is not family land, the use of land is often allowed on the basis of some other social networks, such as marriage.

Profitability of fish farming comparison between this assessment and the ACP study

The ACP study (2013) estimated a total production of 100 kg/2000 m^2 (500 kg/ha) per year for dam ponds at a selling price for tilapia of USD 1.84/kg). This would earn a farmer a gross income of USD 184. If the operational cost were USD 25 per year, the profit would be USD 159. Sankoh (2015) recorded that the mean annual incomes (USD/ha/year) from fish farming decreased progressively with farm size: net profit (USD/ha/year) was USD 1496 ± 80 for small farms, USD 1213 ± 169 for medium farms, USD 460 ± 80 for large farms and USD 1098 ± 62 for all farms. He argued that investment in fishpond farming could be more rewarding than rice farming and similar to tree crop farming, suggesting farmers could continue to harvest every year after the first year of investment in fishpond construction. It should be noted, however, that the decrease in annual income with an increase in pond size could be due to understocking pondssize and inadequate input supply, such as lime and fertilizer. This would not give the expected yields and so not reflect the true relationship between pond size and profitability.

It could be seen that in both the ACP's and Sankoh's (2015) assessments, farmers employed low input and low output farming systems. For example, if farmers received fingerlings or broodstock as a free gift from an NGO or caught them from the wild or only stocked a small amount of fingerlings and allowed them to grow and reproduce in the ponds, in subsequent years the farmers might not buy fingerlings again. Moreover, low input and low output farming systems often do not use fertilizer to bloom plankton or increase natural food for fish in the ponds, nor do they use lime to neutralize acidity in pond water and supplementary feed. This practice may have been largely responsible for the poor growth of the fish stocked in the ponds.

Similarly, the fish farmers did not usually pay for rice bran, termites, etc., so essentially the profit they made from fish farming could be seen as returns on family labor. Assuming that the fish a family eats was bought by the head of the household or family, then it is reasonable to conclude that fishpond farming is profitable. However, because the farmers do not earn physical cash from their farming activities, they do not perceive fish farming or other agricultural production systems as profitable ventures. Large family and household sizes mean that most of what is produced is consumed at the household level with little surplus available for sale. Similarly, because of family ties and social networks, a significant proportion of harvested fish is given away freely as gifts to relatives, neighbors and important people in societies as investments in social capital (Sankoh 2015).

SWOT analysis at FGDs and the FAO consultative meeting

Issues discussed in FGDs included resource availability and suitability, migration to urban areas, farm inputs and support services (especially support from the government and NGOs), fish consumption preferences and fish demand and market opportunities. The results of the discussions are presented in Table 24.

The SWOT analysis showed that central governments initiatives of "the third generation poverty reduction strategy paper," otherwise known as the Agenda for Prosperity (Road to middle income status 2013 to 2018) (GoSL 2012), has provisions for supporting agricultural farming systems (including aquaculture) and nonagricultural livelihoods.


Photo credit: Salieu Sankoh/WorldFish

A crib built in a pond to place organic fertilizer.

Strengths
1. Arable land and water resources are abundant (high rainfall within 6 months of the year and many rivers, streams and lakes).
2. Large extended family sizes and family labor are readily available with a workforce skilled in traditional practices.
3. Strong local and international markets for fish, and livelihood opportunities.
4. There is small-scale support for investment into the sector from NGOs, government and donors (e.g. the German government under the Bo-Pujehun Rural Development Project in the late 1980s to early 1990s; the FAO Technical Cooperation projects from 2009 to 2010 and another ongoing 2015 project; the ongoing USAID-funded WorldFish Integrated Aquaculture Agriculture project; and the various NGOs supporting aquaculture in different parts of the country as recorded in this assessment and earlier ones.
5. There is a long-established fisheries administration, and research structures exist in the country such as the Department of Aquaculture and Fisheries Management at Njala University and the Institute of Marine Biology and Oceanograph, Fourah Bay College, University of Sierra Leone.
6. New fisheries policy and a high profile in the Poverty Reduction Strategy Paper (PRSP) (Agenda for Prosperity) provide proper policy direction in support of aquaculture development in Sierra Leone.
Weaknesses
1. Some land or water use activities are conflicting in nature (e.g. using land or water for irrigating crops conflicts with its use for fishponds at the government hatchery in Makali.
2. Conflict in the use of resources and ranking of aquaculture production is lower relative to other production or farming systems.
3. There is a lack of improved local inputs and support services, especially extension services and fish preservation technology apart from the traditional method of smoking or drying.
4. The level of organization and business skills is low, access to credit facilities is poor and there was no official access to EU markets for fish trade at the time of this assessment.
5. There was poor coordination of research efforts and implementation of recommendations from research findings. Research findings are not communicated to decision-makers.
6. The MFMR is under-resourced and its meager resources are mostly spent on misplaced priorities. This hinders the capacity of the long-established fisheries and aquaculture administration in Sierra Leone to effectively perform its functions for aquaculture extension and training.
Opportunities
1. Many cultivable fish species in the wild are species of preference by the majority of fish consumers in Sierra Leone and abroad.
2. It is possible to enhance existing aquaculture practices through participatory methods of technology transfer and integration.
3. There is potential for expansion of inland fisheries and aquaculture for improved food security and employment of rural poor and wealth generation.
4. Potential achievement of EU seafood quality and safety standards and access to EU markets is possible, considering that it takes only 6 hours to fly to most European airports from Sierra Leone.
5. There is government and donor support for sector development, and a willingness among stakeholders and community based organizations (CBOs).
6. There is plenty of sunlight that can be used as a renewable source of energy for aquafarms and hatcheries.
7. The newly established ABCs could serve as source of aquaculture inputs and supplies and training centers.
8. Producing high quality fish feed and seed in Ghana and Nigeria could make imports of these inputs a lot cheaper than importing fish feed from Brazil, as was done by FAO in the 2009 FAO TCP.
Threats
1. Potential competition between capture fisheries and aquaculture producers and fish stocks is threatened by irresponsible fishing methods.
2. The MFMR is inadequately equipped to implement participatory aquaculture planning and development.
3. Some traditional farming systems are not currently compatible with pond culture of fish, and changes in the priorities of local people in their production activities might adversely affect employment and food security.
4. Uncertain trade barriers and investment risks exist.
5. The infrastructure (road network and electricity), particularly roads, leading to farm sites is poor.

Note: recorded in FGDs and a consultative meeting at FAO.

Table 24. Strength, weaknesses, opportunities and threats to aquaculture development in Sierra Leone.

Aquaculture site suitability models for Tonkolili and Bombali

Spatial distribution of ponds

Tonkolili has more than 75% of the ponds recorded in Sierra Leone (Dabo et al. 2009). This might be linked the fact that it is the only district in the whole country with a hatchery, and this hatchery has a permanent presence of fisheries extension officers and technicians. This is supported by the fact that Bo District, which has an experimental fish farm that also served as a fingerlings supply source, has the second-largest number of fishponds in the country as recorded in the FAO aquaculture baseline survey (Showers 2015). Similarly, the IVSs in Tonkolili were developed under an IVS development project, the IFAD-funded Magbosi Integrated Agricultural Development Project of the early 1980s, making the swamps in this district suitable for pond construction and fish culture.

The more recent proliferation of fishponds recorded in this assessment in Tonkolili District in the past 15 years, particularly between 2000 and 2010, were a result of NGO support (CARE Sierra Leone, MADAM, World Vision and TARP) for farmers who were resettling back into their villages after the civil war. The NGOs provided food for work for farmers who dug or repaired their old fishponds. After the war ended in 2002, many internally displaced people were encouraged by the government and donor agencies or NGOs to resettle in their villages and towns. Some of the resettlement packages included encouraging farmers to rehabilitate their agricultural lands and fishponds. Many farmers therefore dug fishponds, but most of them were abandoned shortly after their construction. This should serve as a lesson for donors and development partners, who assume that quick-fix support for rural farmers in the form of cash, food or tools are useful way of helping poor people get out of poverty. However, longer-term interventions focusing more on knowledge and technology transfer and planning with the beneficiaries are better and more sustainable ways of reducing poverty in rural areas in developing countries like Sierra Leone.

GIS models for selecting suitable sites for aquaculture development in Bombali and Tonkolili

The updating and development of GIS models for site suitability for aquaculture development in this assessment cover 11 chiefdoms in Tonkolili District and five in Bombali District using available dataset (Figure 7). The existing fishpond distribution is shown in Figure 8.

The updating and development were carried out by determining (a) the biophysical and socioeconomic factors for aquaculture development and (b) the geographical and political areas and boundaries that have high potential for promoting fish farming in pond clusters, with an emphasis on commercially viable clusters, which can be connected to small ABCs that can provide inputs and support services (feed, seed and technology) and markets.

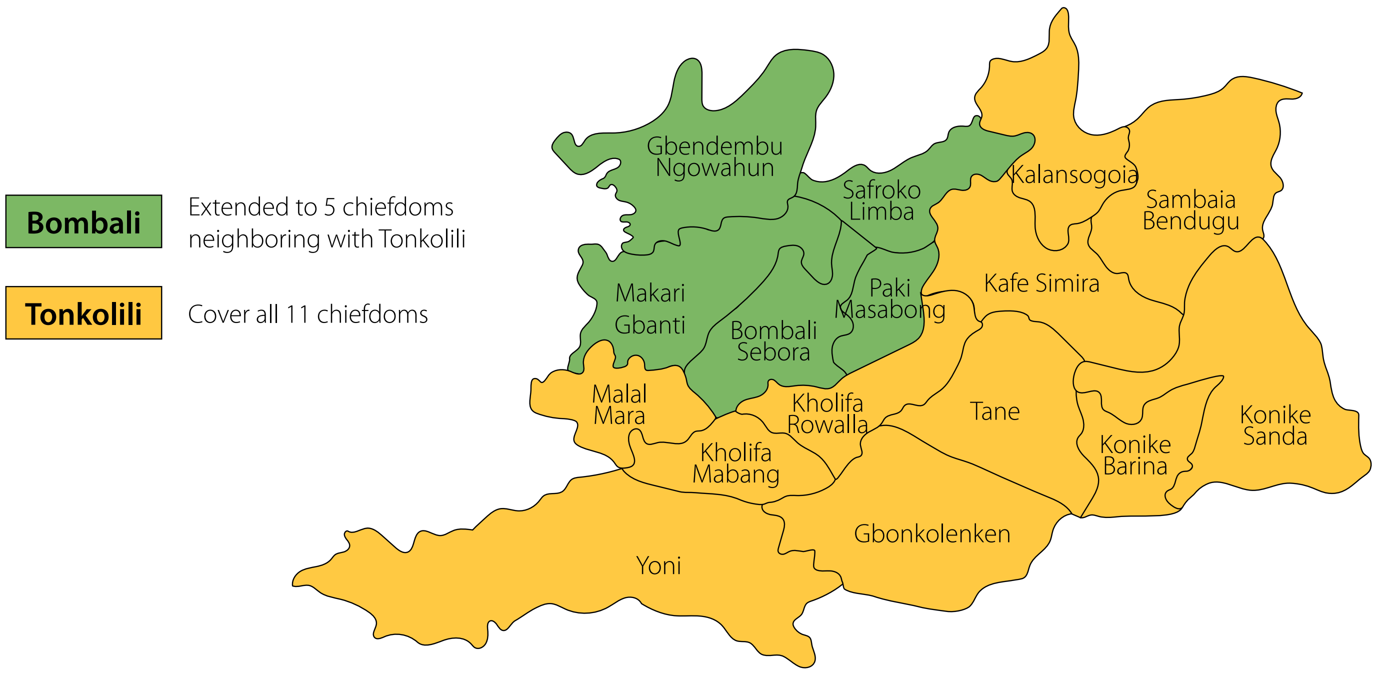
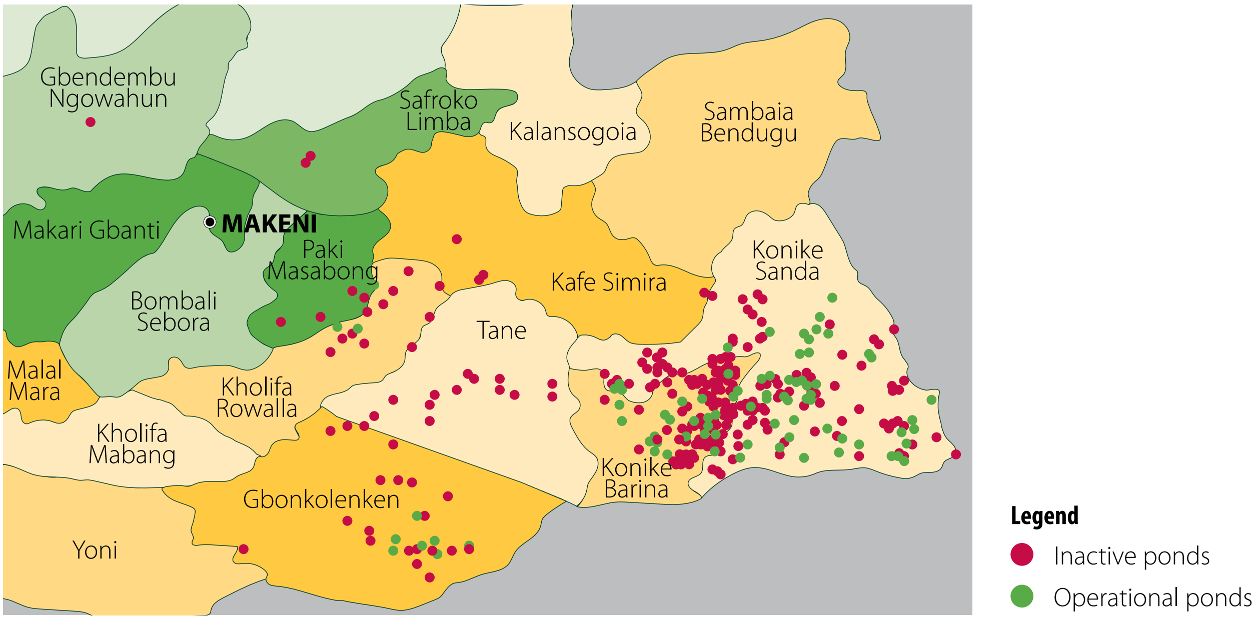


Figure 7. Recommended domains in the study area.

Methodology

A simplified GIS modeling methodological framework developed by Kam et al. (2008) was used for delineating suitable areas for pond aquaculture in the two districts of interest. Figure 9 shows the main steps for defining factors affecting the potential of aquaculture development and outlining suitable aquaculture development sites. The methodology principally applied multicriteria evaluation, combining the multiple factors (or criteria) affecting the suitability of an area for pond aquaculture development using the mathematical technique of weighted linear combination (WLC).



Source: WorldFish (2016a)

Note: Green dots are active production ponds and orange dots are ponds that had either been abandoned or were not actively producing at the time of the assessment (refer to Table 2 for details of pond distribution by chiefdom) as recorded by Sankoh and WorldFish's GIS expert in 2015.

Figure 8. Fishpond distribution in Tonkolili and Bombali districts.

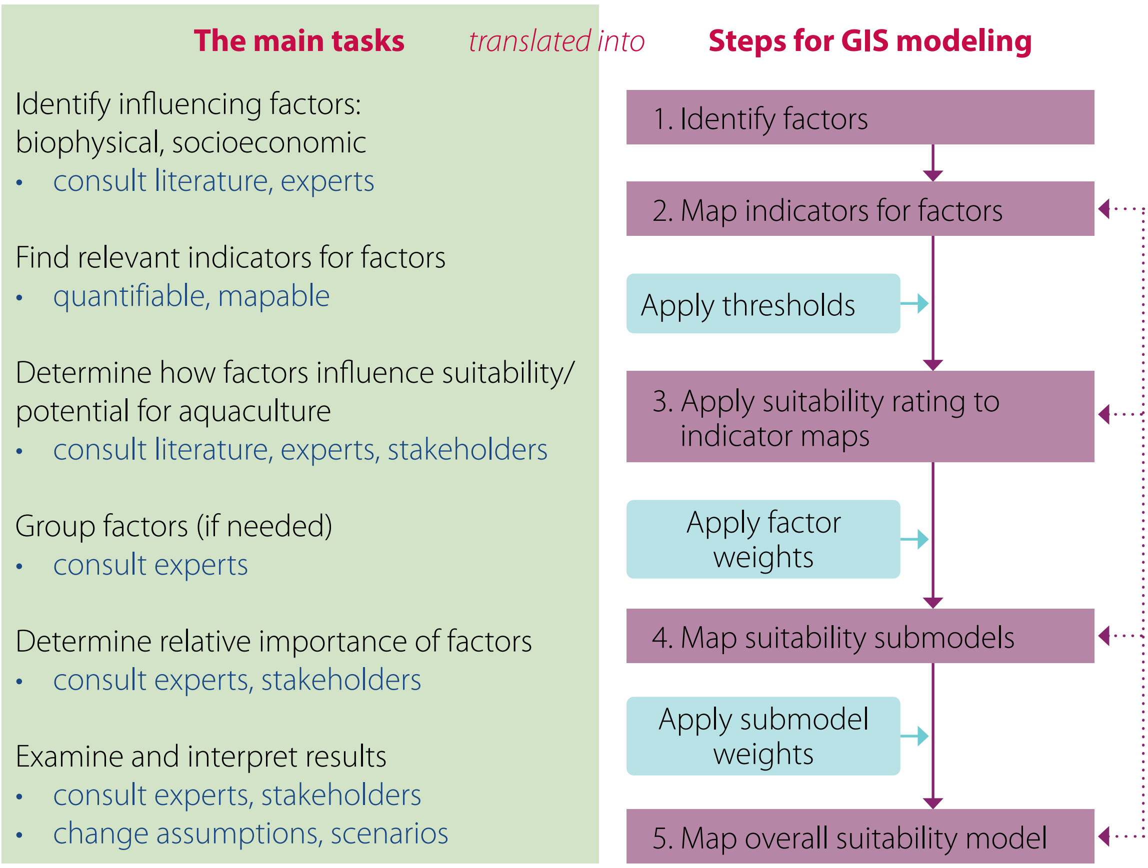
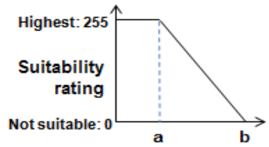
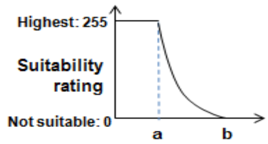
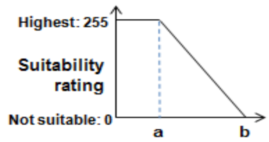
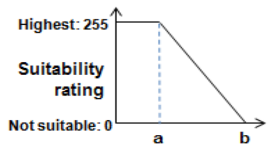
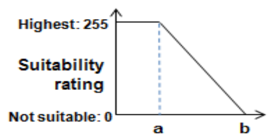


Figure 9. Steps for mapping aquaculture potential.

The GIS modeling process started with the identification of biophysical, political and socioeconomic factors that affect the potential and development of fishpond aquaculture technology in the two districts. The relevant factors (Table 25 and Figure 10) were adapted from Sankoh (2009) and combined with the inputs of the two-day consultative meeting on 1–2 December 2015 at the FAO office in Freetown and one month of PRAs/RRAs in Tonkolili and Bombali districts carried out by the consultant and team. The revised indicators used for the development of the models depended on spatial data availability and their scale at the chiefdom level. For instance, although soil conditions, water balance and the poverty index were identified as important factors affecting aquaculture development, these were not included in development of these models because the available data was at the district level and not at the chiefdom level. Moreover, submodel water and land does not include textural and chemical properties (pH) of soil and essential physical and chemical properties of water. This is also a limitation of the model. Table 26 outlines the important factor indicators and the suitability criteria.

Factor >> Measure of	Interpretation	Suitability
Water and land		
Proximity to perennial water bodies >> Water supply for pond	The closer a water source, the cheaper the cost of channeling water to a pond.	 a=100 m; b=1,000 m
Elevation >> Low-lying areas prone to ponding	Traditional fish farming was carried out in floodplains and IVSs <=150 m. Water flow to lowlands can be by gravity, whereas power may be needed to pump water to highlands, which can be costly.	 a=50 m; b=150 m
Slope steepness >> Ease of pond construction	A gentle slope is easier for constructing ponds and reduces the risk of erosion. Gentle slopes also help drain ponds for harvest and reconditioning/preparing them before restocking.	 a=2; b=8 slope %
IVSs >> Suitable for pond aquaculture	The natural landscape of an IVS to keep water is very suitable for fish farming.	To be developed after collecting the data.
Land use and constraints	Land used for housing development or urbanization may not be available for fishpond construction, such as airports, football fields and protected areas, which may not be available for aquaculture development.	Simply exclude urban centers, protected areas, airports (if they exist in study areas) from suitability maps.
Inputs and knowledge		
Proximity to a government hatchery >> Access to seed	The closer to a government hatchery, the better the access to good quality fish seed and fingerlings.	 a=5; b=50 km
Fishpond densities >> Ready pond to improve or rehabilitate fish production; access to seed and farmer-to-farmer knowledge	The higher the pond density, the easier it is to get fingerlings from nearby ponds and technical advice from other farmers, and the more potential there is to form a fish farmer group or cluster.	 a=0.01; b=0.05 pond/km^2

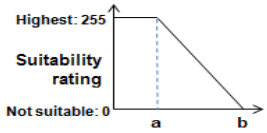
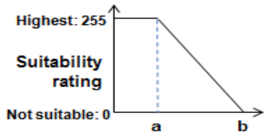
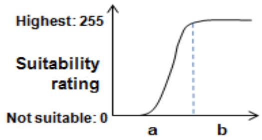
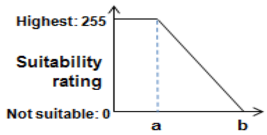
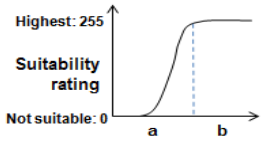
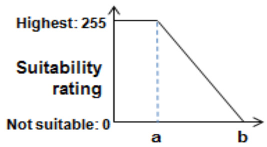
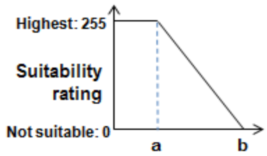
Factor >> Measure of	Interpretation	Suitability
Inputs and knowledge		
Proximity to ABCs >> Access to feed from rice bran	The closer to ABCs, the easier it is to get feed from processing rice bran and plants.	 a=5; b=50 km
Proximity to big towns or cities >> Access to farm tools	The closer to a big town or city, the easier it is to access shops selling farm tools.	 a=5; b=50 km
Population densities >> Access to labor	Higher population densities have more available labor for fish farming work.	 a=60; b=100 people/km^2
Livestock waste >> Available manure for fertilizing ponds	The higher the livestock population density, the more manure is available for fishpond fertilization and the more likely to promote integrated fish farming with livestock rearing.	To be developed after collecting the data.
Market and accessibility		
Proximity to road network >> Infrastructure and accessibility	Better accessibility makes it easier for farmers to sell fish products along main roads and save time to transport fish to main city markets.	 a=5; b=10km
Population densities >> Local demand for fish	Higher population density means higher fish demand.	 a=50; b=70 people/km^2
Access to main markets >> Markets to sell fish	The closer fishponds are to markets, the lower the cost and time of transporting fish to them.	 a=5; b=50 km
Distance from coastline >> Access to sea fish	The farther inland, the more expensive it is to transport marine fish and the better placed inland fish farmers are to compete in price and fish quality supplied to local markets.	 a=20; b=150 km
Average fish price >> Profitability of fish farming	The higher the price, the more profit farmers can make from fish farming and the more attractive it is to sustain aquaculture.	To be developed after collecting the data.

Table 25. Influential factors, interpretation and suitability rating.

All the factor indicators were transformed into standardized map layers with a continuous scale of suitability, ranging from 0 (least suitable) to 255 (most suitable). This soft or "fuzzy" concept (0–255 scale) allocates a value representing its degree of suitability, instead of a hard Boolean definition for any particular location as being absolutely suitable or not for a given criteria condition.

For an easier interpretation, the 0–255 continuous suitability rating system was reclassified into four levels as most suitable, suitable, moderately suitable and least suitable. This final suitability map provides a broad picture of the potential areas for aquaculture pond development, with dark green indicating the most suitable and dark brown the least suitable (Figure 11).

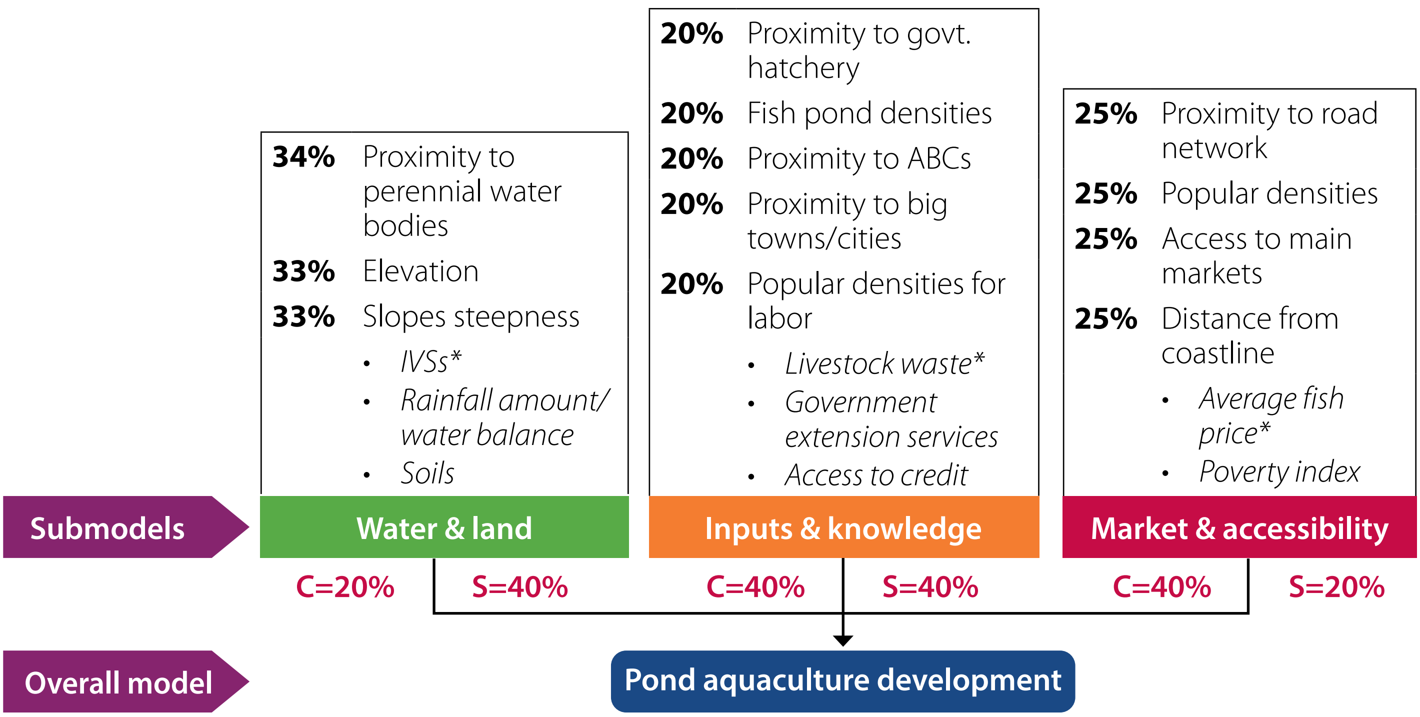
The factors were grouped logically into the following three submodels representing key aspects of their influence on aquaculture potential:
1. natural resources (water and land)
2. inputs and support services (inputs supplies and knowledge)
3. market access and fish demand.

The output suitability maps of the submodels were assigned weighted scores, determined during the consultative workshop, and then combined in the main model to produce the overall suitability map. While constructing submodels and the overall model, factors considered more important were given relatively higher weighting in consultation with farmers and experts. The factor weights preferably were given by local experts and fish farmers during the stakeholder consultation sessions in such a way that they added up to 100%, indicating their relative importance.

Estimated area suitable for pond aquaculture

The final commercial pond aquaculture map showing four suitability classes was used to generate statistics on estimated areas (km^2), which fall under each suitability class—most suitable, suitable, moderately suitable and least suitable—for all chiefdoms (Figure 11).

Gbonkolenken, Konike Sanda and Kholfa Rowalla were the most suitable. The estimated area under the most suitable category in these chiefdoms was notably larger than in others, totaling almost 1260 km^2 (126,000 ha). These chiefdoms were rated most suitable, suggesting they had relatively easy access to big towns or cities, population centers for market, many existing fishponds ready for rehabilitation and convenient access to seed and fish farming



Note:
- C = Commercial; S = Subsistence
- Factors shown in *italics* are lack of data available for modeling
- Factors noted with * are planing to collect the data for improving the model

Figure 10. Biophysical and socioeconomic factors influencing pond aquaculture development in Tonkolili.

knowledge sharing. These chiefdoms also had a large number of IVSs with perennial water supply sources. The assessment also recorded high numbers of fishponds in these areas.

Figure 12 illustrates the use of a drill-down query function to identify which of the specific constraints was encountered at a particular less suitable location.

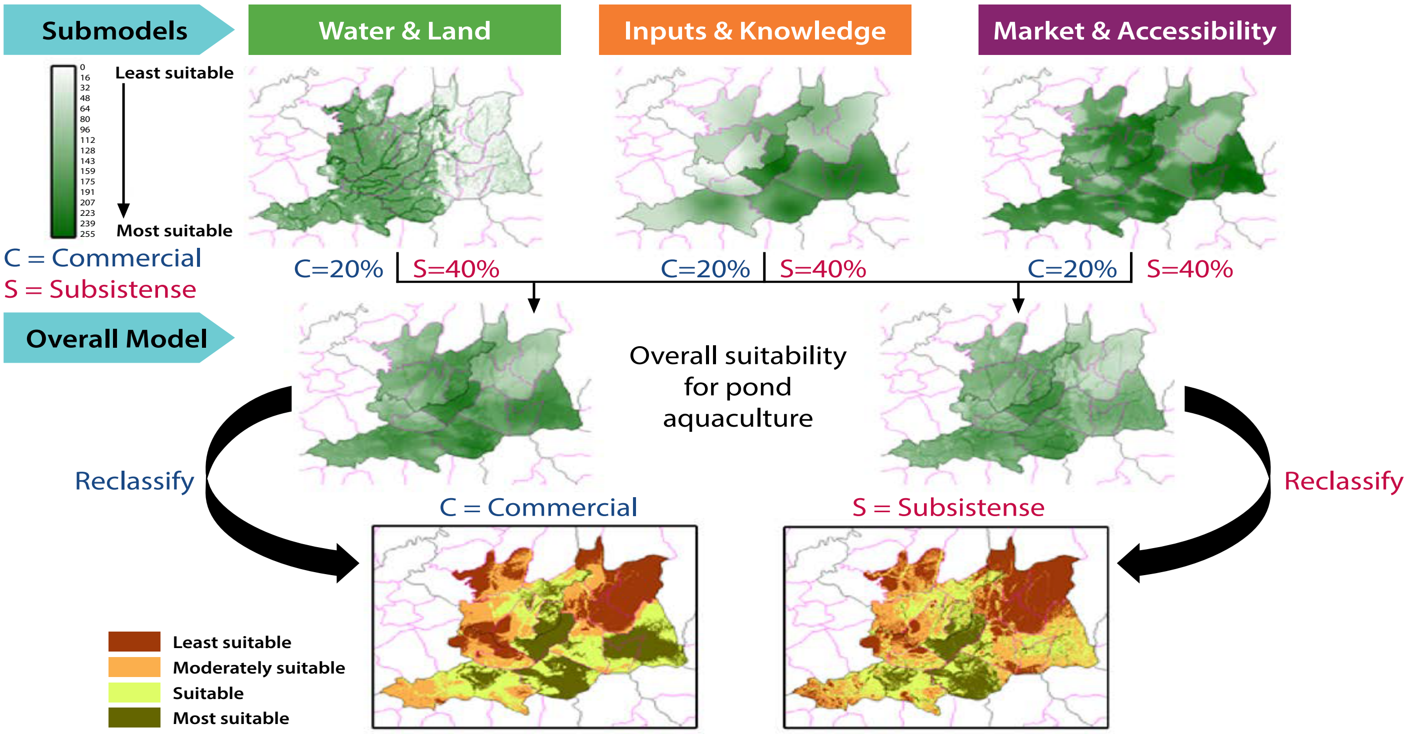


Figure 11. Combining submodels to produce a final model for evaluating overall aquaculture suitability.

Estimated areas (km²) by chiefdom

Chiefdom	Least suitable	Moderately suitable	Suitable	Most suitable
Bombali:				
Bombali Sebora	98.5	148.3	160.5	7.8
Gbendembu Ngowahun	367.4	264.7	13	0
Makari Gbantin	78.7	271.8	157.3	30
Paki Masabong	0	0	56.4	144.2
Safroko Limba	0	48.4	178.8	76.1
Tonkolili:				
Gbonkolenken	0	2.5	218.1	494.8
Kafe Simira	374.7	182.7	15.4	0
Kalamsogoia	256.7	133.8	9.2	0
Kholifa Mabang	82.7	148.7	39.3	0
Kholifa Rowalia	0	1.9	27.1	312.8
Konike Barina	0	20.3	85.1	169
Konike Sanda	0	40.9	324.9	453.9
Malai Mara	167.2	100	6.4	0
Sambaia Bendugu	640.4	5.6	0	0
Tane	15.7	133.1	324.9	39.6
Yoni	20.2	526.3	568.4	154.9
Total	**2,102.2**	**2,029**	**2,184.8**	**1,883.1**

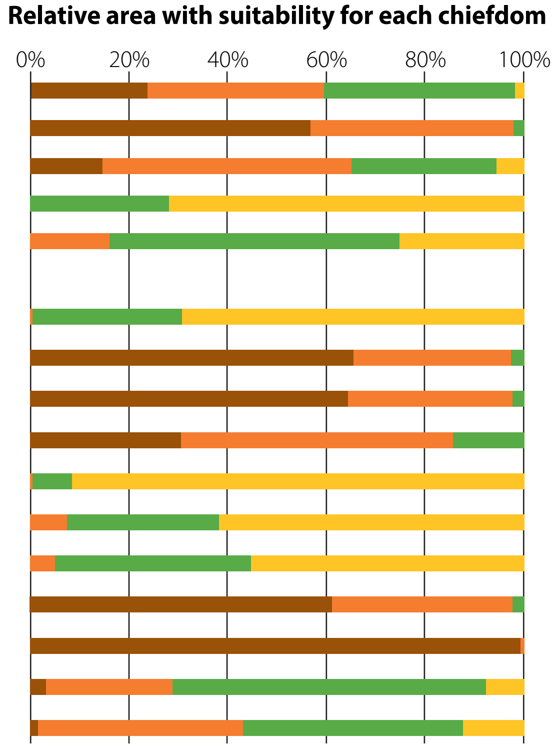


Figure 12. Estimated areas (km²) under four suitability classes, by chiefdom.

The work indicates the potential advantages of using GIS to provide guidelines for policymakers, aquaculture planners and extension workers in the development of strategies for harnessing aquaculture development potential in Tonkolili District and to identify relevant interventions for promoting freshwater aquaculture.

Harnessing fish production potential

Aquaculture development potential

The suitability analysis for pond aquaculture development was largely based on the scale and quality of data available. Some data was represented as being uniform for an entire chiefdom or district, which is likely overestimated because of unavailable disaggregated data. Therefore, it would be unrealistic to aim at harnessing the full potential. Nevertheless, achieving only 5% of this potential would substantially increase the total fish supply in the country if estimated production is 2.73 t (3.0 tons) per hectare (Table 26). Annual per capita consumption of fish and aquatic products could then be increased accordingly.

The GIS models developed in this assessment identified and mapped out areas considered suitable for aquaculture production at commercial and subsistence levels based on the agreed criteria. They serve as a guide for developers and investors but do not tell what level of investment would be economically viable. A separate economic feasibility study and cost-benefit analysis has been done in this assessment (Section 3.13).

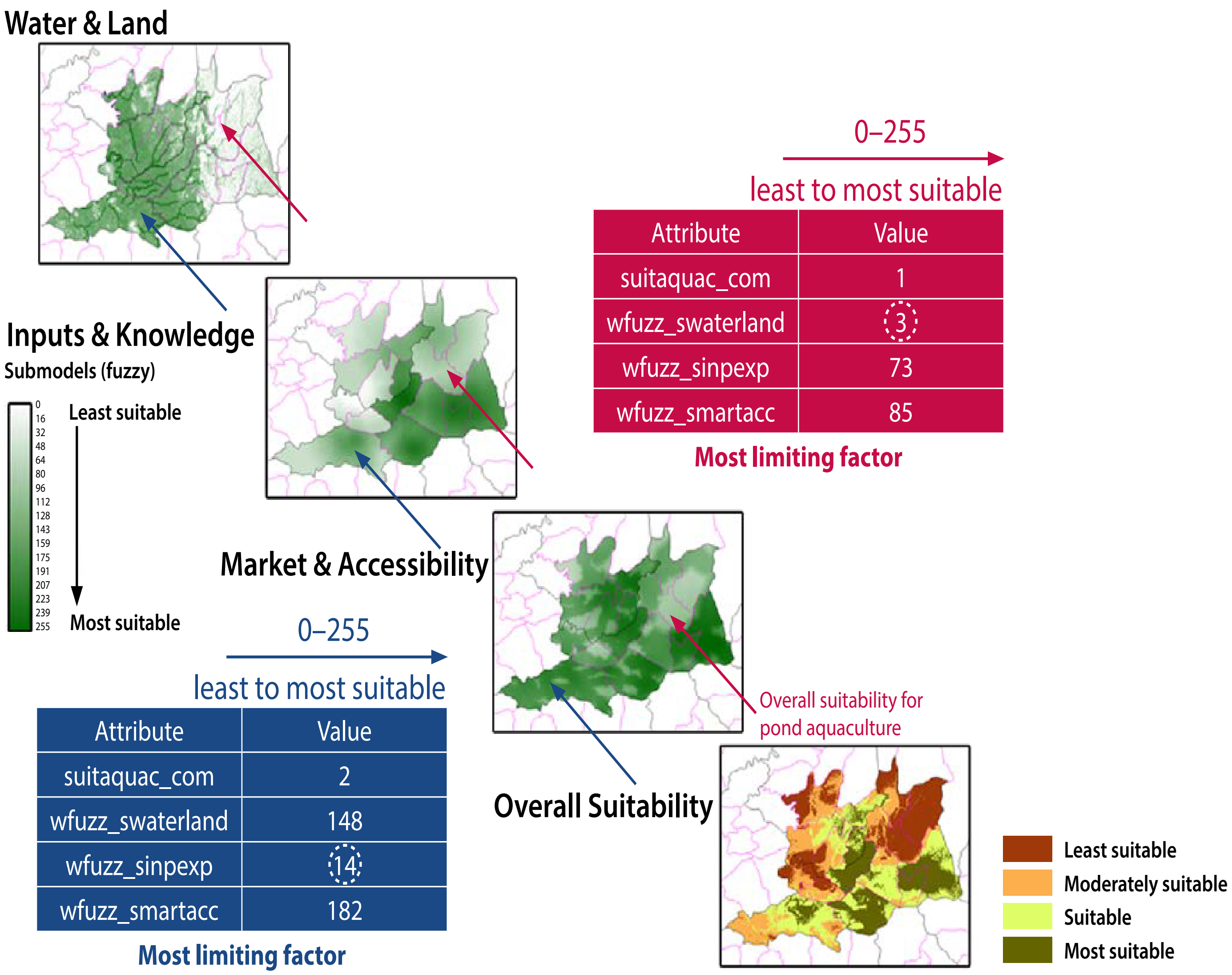


Figure 13. Querying the maps shows factors limiting potential at each specific location.

Chiefdom	Total area of most suitable sites (ha)	Production (t) per annum	10% area (ha)	10% production (t)	5% area (ha)	5% production (t)
Bombali						
Bombali Sebora	779.2	2,337.7	77.9	233.8	39.0	116.9
Gbendembu Ngowahun	-	-	-	-	-	-
Makari Gbanti	2,996.2	8,988.6	299.6	898.9	149.8	449.4
Paki Masabong	14,424.5	43,273.4	1,442.4	4,327.3	721.2	2,163.7
Safroko Limba	7,605.1	22,815.3	760.5	2,281.5	380.3	1,140.8
Tonkolili						
Gbonkolenken	49,478.0	148,434.1	4,947.8	14,843.4	2,473.9	7,421.7
Kafe Simira	-	-	-	-	-	-
Kalansogoia	-	-	-	-	-	-
Kholifa Mabang	-	-	-	-	-	-
Kholifa Rowalla	31,281.4	93,844.2	3,128.1	9,384.4	1,564.1	4,692.2
Konike Barina	16,899.0	50,697.1	1,689.9	5,069.7	845.0	2,534.9
Konike Sanda	45,393.2	136,179.6	4,539.3	13,618.0	2,269.7	6,809.0
Malal Mara	-	-	-	-	-	-
Sambaia Bendugu	-	-	-	-	-	-
Tane	3,960.1	11,880.3	396.0	1,188.0	198.0	594.0
Yoni	15,492.1	46,476.2	1,549.2	4,647.6	774.6	2,323.8
Total	**188,308.8**	**564,926.4**	**18,830.9**	**56,492.6**	**9,415.4**	**28,246.3**

Table 26. Aquaculture development potential in Tonkolili and Bombali districts.

General discussion of assessment findings, conclusions and recommendations

This assessment addresses a simple question: Can sustainable, financially viable aquaculture be developed and promoted in Sierra Leone, particularly in Tonkolili, from its current low levels?

As in other earlier studies and assessments, such as ACP Fish II, the NEPAD Governance Working Group on Aquaculture and Sankoh (2009), this study found that Tonkolili District has the highest number of fishponds in Sierra Leone. Out of 2590 ponds in the country reported in the ACP Fish II study, this assessment documented 2056 fishponds in Tonkolili alone. Although over 90% of these fishponds were abandoned or not in active production at the time of the study, farmers in Tonkolili had once invested time and labor in some form of fish farming. This study has therefore set out to determine why the rate of abandonment was so high in the district, where aquaculture was first introduced in the 1970s.

It was assumed at the start of this assessment that people are readily convinced by donors or consultants to construct fishponds. However, these ponds are quickly abandoned shortly after construction because of cultural, social, knowledge, legal, economic, political or physical (natural resources) reasons. These initial assumptions are summarized as follows:

- Rural farmers do not have a tradition of domesticating/culturing fish in Sierra Leone (cultural barrier).
- Most rural farmers lack the technical knowledge required to grow fish in ponds (knowledge barrier)
- Many rural farmers do not have secure access to land and water resources to invest in aquaculture (legal barrier).
- Either access to inputs and support services is insufficient or the costs are prohibitive in the areas where aquaculture is currently being practiced, mostly Tonkolili, Bombali and Bo districts (economic and political barriers).
- There is insufficient time and interest among local people who are preoccupied with other less risky and more profitable livelihood activities (economic barrier).
- There is insufficient demand for freshwater fish (cultural barrier).
- Market infrastructure is not good enough to support widespread aquaculture in Tonkolili, Bombali and Bo districts (economic barrier).
- Either suitable land for aquaculture (topography, soils, water) is insufficient or site selection for fishpond construction in the Bombali, Bo and Tonkolili districts has been poor (physical resource barrier).

Cultural barriers

Some form of traditional aquaculture system exists in the two districts assessed, and farmers employ a variety of techniques to exploit local conditions and the behavior of fish to increase their harvest. The techniques and methods included trapping fish in holes and ponds left behind by mining activities, aggregating wild fish in vegetation parks, isolating fish in natural bodies of water through fish fencing, and stocking fish caught from the wild into earthen fishponds or drinking water wells. The lack of uptake of modern aquaculture or the abandonment of ponds shortly after construction does not therefore appear to be related to the types and extent of local or traditional aquaculture. Rather, it may be a result of a lack of capital to invest in more capital intensive production methods and systems. It can be likened to other livestock that rural farmers raise, most of which are free range. There is general ownership of goats, sheep and poultry, but farmers do not feed these animals. Instead, they are left to fend for themselves from the wild and return to the house or shed in the evening. Similarly, many women still revisit abandoned ponds to harvest fish that have not been fed or cared for in the true sense of pond aquaculture.

Knowledge barriers

It was an assumed that the pool of knowledge about aquaculture within populations of rural farmers in the area of interest is too small and scattered to be useful and that local knowledge of farmers is only relevant to hunting, gathering or fishing from the wild, not for farming fish.

The widespread use of traditional systems of aquaculture in Tonkolili District demonstrates that rural farmers have valuable local knowledge that could have applications in modern aquaculture production systems. However, this pool of knowledge is not consolidated and is mostly restricted or held by very old people and certain members of secret societies. The local knowledge in existence in the study areas was relevant for aquaculture development and promotion.

Taxonomy

Local criteria for naming fish and the names of fish appear to be consistent. They are coherent across wide areas and are relevant for stock assessment and a valuable basis for biological studies. They also guide local people's resource conservation behavior, as well as farming and fishing strategies, and they are essential for predicting situations where farming and fishing can be successful (Ruddle 1994). The farmers, particularly the women, also knew what the fish eat and could differentiate between male and female fish very easily. This knowledge would be valuable in monosex fish culture and fish feed formulation.

Habitat classification

Common applications of local knowledge included baiting fish traps and pots, and fish concentration techniques used for fish fences, ponds and vegetation parks. Knowledge of fish migrations in the rainy season is used for the construction of parks and fences. Local habitat classification and naming give an idea of local people's dependence on the natural environment and its resources (Lalonde 1993).

Fish ecology and management

Knowledge of fish ecology was used in four ways in fisheries management: (1) closed seasons, (2) a total ban from exploitation in "sacred areas," (3) a ban on use of ichthyo-toxic plants and chemicals and (4) the use of selective traditional fishing methods.

Based on the above findings, there is no absolute lack of knowledge, but its restriction to particular members of the society might make it inaccessible and not useful. Knowledge of fish and traditional fisheries is widespread but very unevenly distributed. Some knowledge is not accessible because it is tied to secret societies ("Bundu," "Poro," "Wonde," "Mathoma," "Gbangbani," etc.). Other knowledge seems to be the preserve of the older members of the community. The extent to which this knowledge is vulnerable to being lost, given the high rate of illiteracy (among other issues) is difficult to determine. It is reasonable to say a few local farmers have some local technical knowledge of fish and fish farming, but it is restricted and therefore needs to be documented and shared more widely for it to be useful in fish farming development and promotion.

Access to natural resources for pond aquaculture promotion and development

Secure access to land and water resources is an important prerequisite for the development and promotion of aquaculture. In the capital and other cities, land is expensive and prices are increasing. If these trends were the same in rural Sierra Leone, it would be extremely difficult for poor, landless farmers to gain access to required land and water resources for aquaculture production.

Access to land

Land in rural Sierra is generally family property. Heads of the family administer and allocate plots of land to members and sometimes nonmembers who may be connected to the family by some social networks, such as marriage. The chiefs and village headmen control substantial areas of arable land in the rural areas and are in many ways connected to their subjects and communities, especially through marriages. A chief can marry as many wives as he chooses and so have many in-laws, who can in some way benefit from the chief's lands through temporary access for agriculture purposes.

In Freetown and other cities like Bo, Makeni, Kenema, land can be bought, but most often plot sizes are much smaller than one could obtain if the same tenure system was applicable in the provinces. However, there are ongoing land reforms by the government's Ministry of Lands, Country Planning and the Environment that are geared toward promoting commercial agriculture production. They would provide an opportunity to lease large pieces of land for a long period of time that could attract large-scale investment in agriculture and aquaculture.

Free access to communal farmland and the lack of availability of inorganic fertilizers might be the reasons for the persistence of traditional agriculture production systems (especially shifting cultivation, slash and burn, and bush fallow), which have been identified as obstacles to pond culture of fish in the country. However, the combined pressures of population growth and increasing commercialization of agriculture have served as drivers of change from communal tenure systems to an individualized and market-based land tenure system (Bruce 1986). For example, the commercialization of agriculture that started with colonization, when commercial crops such as oil palm, cocoa, coffee, cotton, tobacco and others were introduced, tended to be associated with the rise of individualized land tenure and a greater incidence of land transactions (Adesina 2002; Berry 1984; Kallen 1996; Lawry 1993; Platteau 1992).

In conclusion, the average population density in Sierra Leone is currently less than 75/km^2, and access to land and water resources is possible for most people through elaborate social networks. Access to land by "foreigners" is currently severely limited, and what constitutes a foreigner might be widely or narrowly defined, depending on local circumstances. The government is now able to negotiate land lease agreements to facilitate large-scale investment in agriculture and therefore aquaculture. Village chiefs in Tonkolili District also confirmed that they would readily lease land to investors, because this would bring job opportunities to their localities for their children. The chiefs said they do not have the capital to cultivate all the available land in their places, so if someone comes to them with the required capital, they would work with them.

Access to credit

Community members live very close to each other and share resources. They form social structures like financial and labor clubs to support each other in times of need. These structures were reported to be very efficient as means of investment and access to credit in the absence of formal financial institutions (Richards, Bah and Vincent 2004). In addition, in the absence of social security and safety nets from central and local governments, family members and friends are the last resort for help in difficulties times, and the same networks were also reported to be what landless members of the rural communities used to accessed land resources.

Economic barriers cannot absolutely prevent the development of aquaculture and agriculture. The informal financial clubs, which have now been formalized by MAFFS and the community banks, are now making it possible for farmers to access reasonable amounts of money as credit facilities in the rural areas. More recently, the World Bank approved a USD 3.5 million grant to the GoSL in support of strengthening community banks and FSAs.

Inadequate access to inputs and support services or prohibitive costs of inputs

The consultant and team had assumed that modern aquaculture production would require inputs such as machinery, manufactured feeds, improved fish seeds, water quality testing, treatment equipment and technical expertise, all of which are currently not manufactured or produced in Sierra Leone and may need to be imported. Similarly, the poor road network and the lack of fish processing infrastructure and cold chain in the country could serve as barriers to the success of aquaculture development in the country.

Inputs and support services

Political structures at the central and local government levels affect government policies, infrastructure, inputs and support services for aquaculture development in the country. In many communities, NGOs have been instrumental in supporting development efforts in line with food security and poverty reduction strategies, such as assisting local communities with food for work or tools for work for constructing fishponds.

Private sector investments in the supply of aquaculture inputs have not been considered a profitable investment, so they are not attractive to business people. The few farmers currently in fish farming are doing so at subsistence levels, so they cannot buy expensive imported inputs. The inputs could be a lot cheaper and more affordable if they were produced in Sierra Leone, and the private sector might be able to profit from selling such inputs.

Family and household structures and social networks in the communities were very important in facilitating knowledge sharing, at least along family lines. Many farmers said that when they require technical advice on fish farming, they rely on other farmers in their communities because government extension agents from the Ministry of Fisheries are not available.

GIS models developed in this assessment suggested that inputs and support services are the most limiting of all the three submodels (natural resources, inputs and support services, and markets). Technical inputs, made up of extension services and training, were the most limiting. Access to credit facilities and labor were not limiting because large family sizes and the use of free family labor was common practice and informal social institutions (labor clubs) and financial institutions served as alternative sources of credit and investment in the rural settings (Braima 1994; Conteh and Braima 2003).

As previously stated, the government hatchery built in Makali to produce tilapia fingerlings for local farmers to use was not in operation at the time of this assessment. Even when the hatchery is rehabilitated, the challenges of getting the fingerlings to farmers will still remain, because the road networks to the farm sites are poor and the only public transport system that can reach some of the farm sites are motorcycles, which are relatively expensive and unsafe for transporting fingerlings and farmers.

Prospects

Full implementation of the ongoing WorldFish and FAO/TCP project would help provide easy access to good quality fish seed, feed and manure. It would also allow access to short-term technical support services that can help improve the technical know-how of fish farmers and their fish production, backed with sound government policies and an enabling environment for the private sector to play an integral role in the production and distribution of quality fish seeds (fingerlings) and feed. WorldFish's longer-term role would be limited to training and giving technical advice because it is not a business enterprise to sustain the production and supply of farm inputs. However, it could facilitate business planning to set up hatcheries and fish feed production facilities by the private sector as businesses in support of fish farming in Sierra Leone.

In conclusion, inputs and support (extension) services for aquaculture were effectively nonexistent during this study. However, ongoing WorldFish and FAO/TCP projects, if properly implemented and possibly extended for at least another 3–5 years to test business models for fish farming with technical advice to farmers, would improve the productivity and profitability of fish farming.

Access to credit through formal arrangements, such as banks, is almost impossible, but local arrangements exist where modest amounts of money can be made available through microfinancing by FSAs. Significant sums of money can now be borrowed through FSAs and community banks, and this could help improve the uptake of capital intensive agriculture and aquaculture in Sierra Leone. The government and its development partners might need to implement a lands valuation and legal registration program in the provinces to enable rural farmers to use part of their lands as collateral in accessing bank loans, at least from the community banks, to invest in agriculture and aquaculture.

Time limitation and lack of interest among farmers to take up fish farming

Rural farmers in Sierra Leone had various livelihoods options and made choices based on sound economic and social reasoning. These farmers had been growing crops and fishing or hunting for a long time before the introduction of fish farming in earthen ponds in 1976. The introduction of "new" livelihoods into communities was tested by the farmers to compare them with existing alternatives. Although these farmers may have been using traditional methods of farming fish (e.g. trap ponds, vegetation parks and fences), they were never used for rearing or feeding fish in those systems, so farming fish in fishponds and feeding and caring for them would have been regarded as a new technology altogether.

Competing activities

When asked about all their livelihoods activities (farming, trading, fishing, etc.), farmers in Tonkolili District said that traditional agricultural production of swamp and upland rice using shifting cultivation, mixed cropping, bush fallow and crop rotation farming systems were the most common and ranked very highly. The relative importance of the different livelihood activities seems to be based on the following combination of criteria:

- Rice: The staple food in these districts and for most Sierra Leoneans is rice, which is synonymous with food, and therefore it is important to have enough of it to feed the family.
- Income: Some crops (e.g. oil palm, groundnuts, bananas, plantains and pineapples) are grown because they generate cash needed for school fees, medical expenses and repayment of debts.
- Long-term security: Tree crops are grown because they keep producing (bearing fruits) every year with little effort from the farmers and are considered very useful to older farmers who can no longer work as hard as they could when they were younger.
- Food security: Crops like millet and cassava are available in the "hungry season" (July–September) when stored rice is getting low and the new crop is not yet ready.

Overall priorities and considerations for all production systems (agriculture and fish farming) were focused on household consumption, with little emphasis on wealth generation. Religious beliefs, social structure and a strong culture of sharing resources restrict the opportunities for accumulating wealth as material possessions.

Farmers engage in fish farming for both household consumption and income generation, so fish farming stands a chance of gaining a higher ranking among rural livelihoods options if its tangible benefits are demonstrated to rural farmers. The economic evaluation of Sankoh (2015) showed that fish farming could be profitable, but at the moment the farmers do not appreciate the economic benefits because they receive less than 50% of the output as cash. About half of the fish they produce is consumed at the household level and 10%–20% of the harvested fish from the big harvest is given away freely to friends and relatives or important people in the communities.

Available time

Farmers are all very busy during the rainy season, especially at the beginning when they are planting in the uplands and swamps. At the height of the rainy season, there is less work, but as it is the "hungry season" heavy labor is unattractive and the conditions are difficult. Farmers are less busy in the dry season between the rice harvest (December–January) and clearing next year's rice fields (March–April).

Traditional fish farming is also dependent on rainfall to effect the required changes in rivers, streams and floodplain water levels. It would appear that only farmers with enough field hands might be able to effectively integrate fish farming in their other farming systems. This could also be the reason why abandoned fishponds are more widespread, because the farmers spend more time only on constructing the ponds and continue harvesting fish with little management.

In conclusion, farmers in Sierra Leone have a clear and consistent set of priorities, so aquaculture activities have to fit within those priorities. There is only a relatively short period (late January to early March) when farmers have ample free time and are well fed, and this coincides with the period when most ponds recorded in Tonkolili and Bombali districts were constructed. During other times of the year, crop farming is the priority and farmers have less time to care for fishponds. This is why so many fishponds have been abandoned and why those that have not been abandoned are in a poor state of care during most of the year. This will remain so unless fish farming is promoted as a business, not only for farmers but also other potential investors and interested parties.

Low demand for cultured freshwater fish and market infrastructure to support widespread aquaculture

Fish supply and demand

Fish traders said that fish demand and supply were highly variable and seasonal in nature. Fresh fish were uncommon but in high demand and expensive in urban markets (Makeni, Magboraka and Masingbi). Some species command a premium, but consumers are sensitive to price. The inability of the majority of consumers to pay for fish seemed to be the problem, with 58% of the population below the threshold of USD 2 per day. Fish traders in the study areas said they used two strategies to clear their stocks when sales are low and fish spoilage is threatening: lowering their prices (almost always successful) or giving the fish on credit to smaller traders who sell the fish later and pay. Competition from other nonfish animal protein sources (livestock and poultry) was generally not limiting because price-wise fish has a competitive advantage.

Fish processing and preservation

Processing and preservation is predominantly done by smoking or drying, and these methods allow for a relatively short shelf life. There were seasons when fish demand far exceeded the supply, and other times when some weekly markets were flooded with fish and demand was lower than supply. Less than 1% of traders interviewed had access to cold storage facilities in Makeni.

Wholesale and retail fish market structure

There is a complex but apparently efficient network of markets for fish, though there are no dedicated fish markets where only fish is sold. Weekly fish markets are evenly spread throughout the two districts. Fish bought from coastal fishing villages are transported into these networks of weekly markets within a day's travel, and the fish products quickly spread into permanent daily markets in cities and villages. A fish may pass through five or six traders before it is finally consumed, and market traders respond rapidly to changing market conditions.

Just before this assessment, the general market infrastructure in Sierra Leone had deteriorated significantly during the Ebola outbreak in West Africa, which disrupted business for a year and a half. Ebola is transmitted through bodily contact, so the government banned public gatherings, where the likelihood of bodily contact was high, and imposed travel restrictions, which meant that fish traders were unable to travel to fishing villages and fish landing sites to buy and sell fish. Weekly markets, which were mostly supplied by traders who travel from place to place, became only partially operational or were closed down completely. Conditions in the general markets where fish is sold are generally poor throughout the year, with most facilities, such as storage, cold stores, fresh water and washing facilities, are either lacking or inadequate. Heavy rainfall for half the year disrupts trading activities since many of the roads are in a poor state of repair, and the lack of storage leads to spoilage of fish and increases the cost for the consumer.

The poor state of the road network, transportation system and market infrastructure adds to the cost of fish and increases wastage and postharvest losses. However, there is a widespread, well-understood and dynamic system for marketing fish with knowledgable and adaptable traders. Fish is the main source of high-grade protein consumed by all Sierra Leoneans, and freshwater fish delivered fresh into the markets commands a premium, particularly in the interior of the country.

Lack of or insufficient suitable land/sites for aquaculture

Aquaculture development, particularly using earthen ponds, requires a good quality water supply, adequate slopes for draining ponds, suitable soils to hold water with little seepage and optimum water temperatures to support fish growth. It was assumed that the land farmers selected for pond construction in Tonkolili and Bombali districts was not suitable for the production systems, which is why the ponds were soon abandoned.

Data for soil and water quality, which are major factors to consider when selecting a site for constructing a fishpond, was limited at the chiefdom level for the development of this model. However, models developed by Sankoh in 2009 used water balance, perennial water bodies and water temperatures as indicators for water availability and quality, and they used the FAO soil suitability classification for rice paddy production together with slopes and elevation as a measure of soil suitability. Results of that work indicated that Tonkolili and Bombali districts were some of the most suitable areas in the country. Refining the models at the chiefdom level cannot therefore be severely limited by the lack of soil and water quality data. Besides, the suitability models simply provide a broader picture to use as guide in carrying out a detailed assessment or ground truth of a site when planning to develop a fish farm, particularly for commercial production. The factors, weights and thresholds for the suitability rating were based on a consultative meeting of a small group of farmers and experts. It is recommended that this report be presented to a broader group of experts and farmers to get feedback at a validation workshop.

The natural resources submodel showed that Gbonkolenken, Konike Sanda, Konike Barina and Kholfa Rowalla were the most suitable chiefdoms and where the estimated area under the "most suitable" category was notably larger than other chiefdoms, totaling almost 1260 km^2.

Generally, water availability (not quality) was the limiting factor in the natural resources suitability model. Distinct dry and wet seasons certainly affected production systems that basically depended on water level fluctuations caused by rainfall. However, simple engineering modifications such as damming some water bodies in highlands could change the model prediction by storing large amounts of water in the dam in the rainy season and using it in the dry season for production sites that might otherwise dry up. Similarly, the use of dammed ponds for integrated rice and fish farming would be another way of saving water in the production sites instead of allowing it to flow downstream through dikes and making it unavailable to the ponds in the dry season.

It is also worth noting that these models were only applicable to pond fish farming. Other modern fish culture systems like concrete tanks, fish cages in rivers and lakes, and recirculation aquaculture systems (RASs) could completely change the outlook of the models and bring many areas of the two districts specifically, and the whole country in general, under the "most suitable" category of the models.

Compared to earlier models, the inputs and support services submodel has greatly improved with the introduction of ABCs and FSAs, and the improvement of the road networks has meant that feed inputs and more formal credit access systems are now possible in many parts of the study areas. Paved roads and the availability of motorcycles as public transport would also support fast delivery of fish seed to production sites and harvested fish into market centers.

It can therefore be concluded that there is sufficient suitable land and water supply if properly harnessed for the purpose of extensive, semi-intensive and intensive fish farming in Tonkolili and Bombali districts and, indeed, the whole of Sierra Leone.

Economic viability of fish farming in Tonkolili and Bombali

Fish farming in the districts of Tonkolili and Bombali using fishponds is economically viable and could be described as a profitable production system. However, the level of profitability recorded in this analysis is not seen as such by local farmers who are engaged in the production system. Possible reasons why farmers do not see fish farming as a profitable venture include the following:

- Money estimated as income from the production systems in this analysis is not all received or realized in cash by the farmers.
- Of gross income recorded in the study, 27% is actually fish consumed by farmers and their families.
- An additional 8% of income comes from fish that the farmers used as fingerlings or broodstock for subsequent production cycles.

- The 44% of total income that farmers reportedly receive at the main harvest is also not always in cash. Farmers said they exchanged some of their fish for other produce, like rice, cassava, palm oil and magi.
- Farmers in rural Sierra Leone do not seem to attach actual monetary value to labor and the food they eat, so it is likely that they would not perceive the fish they eat in their households as income in monetary terms coming from fish farming.
- Farmers invested a lot on what social scientists would term social capital. They were seen to give a good quantity of their harvested fish to friends, relatives and important people in the communities.
- The fish that were given away were estimated in total income from the main harvest accruing to farmers, but the farmers did not actually receive it as actual cash.
- However, if the analysis included intangible benefits that farmers receive, then fish farming could be seen as a profitable investment with both monetary and social rewards. These benefits include social kingship and capital, which could later yield indirect benefits to the farmer in the form of free labor in future work, protection from chiefs if the farmer has a problem in the village and support from the chief if he complains of a thief having stolen his fish.
- (Fish) farmers in Sierra Leone have a clear and consistent set of priorities, so aquaculture has to fit within those priorities.
- There is only a relatively short period when farmers have much free time (late January to early March), and this is when they are often busy with other activities, such as marriages and social events.
- Farmers recognize that tree crops provide long-term benefits after they have been established, so fishponds could be seen in a similar manner.

Recommended interventions to develop aquaculture in Sierra Leone

Recommendations for policymakers and planners

- Encourage commercial aquaculture production using affordable technology so that farmers will appreciate the monetary value of fish farming. The main focus of the government and development partners has been to promote aquaculture for food security and nutrition in rural Sierra Leone. The focus should shift to the promotion of private sector investment in aquaculture and job creation.
- Support hands-on practical training programs for young staff of the MFMR, and develop curricula for mid-level training of fish farm technicians at university and polytechnic institutions.
- Ensure that the MFMR cooperates and collaborates with MAFFS in the areas of extension services for aquaculture development. The agriculture ministry already has agriculture extension officers in all districts and chiefdoms in Sierra Leone, but the Ministry of Fisheries only has aquaculture and inland fisheries extension officers in Makali. The MFMR should spread the services of agriculture extension officers by training them on aspects of aquaculture. This cooperation and collaboration would ensure that agriculture extension officers would acquire the technical skillset to deliver services to fish farmers, who incidentally are also crop farmers in the country.
- Incorporate training and research in the hatchery at Makali and the experimental station in Bo so that there are trained, qualified and experienced hatchery managers in these stations. Research trials should include growth performance of different species of fish fed with locally formulated feeds along with the domestication and propagation of locally available wild fish species of high nutritional and market values.
- Encourage recordkeeping at the government hatcheries, use feeding tables and ensure fingerlings are sexed. Recordkeeping should also include income generation from fry/fingerlings and broodfish sales. The income generated from the government hatcheries should be invested in improving them and meeting the operational expenditure.
- Strengthen extension and support services as well as other forms of training activities for rural farmers on farm management and simple bookkeeping so that farmers can fully appreciate the monetary value of their farming systems.
- Make irrigation infrastructure and equipment along with materials for intensification and high-yield farming systems available to farmers at affordable prices. Postharvest interventions must be improved to increase value-added, agro-processing activities and also reduce postharvest losses through improved storage facilities.
- Market linkages must be in place and information of competitive market prices available and timely. Market intelligence can now more easily be promoted and used through mobile phones and farmer-based organizations (FBOs).
- Government and development partners must strengthen the ABCs operationalized by three to five FBOs that function as the primary gateway to commercialization for smallholders. Nonfunctional ABCs should be handed over to the private sector so that they can be sustainably operated by

businesses that can make the services of these centers available to farmers more effectively.

- Government, development partners and the private sector must support and strengthen the FSAs in the form of limited short-term loans for economic activities, including aquaculture, while community banks, as limited liability companies, should offer a wide range of financial services to advanced smallholder farmers so that farmers who do not have collateral can access loans through FSAs and community banks.
- Currently, there are no reliable statistics on aquaculture production. Available aquaculture production statistics certainly underestimate the contribution made by small-scale household fish producers. Reliable statistics can influence policy directions to build effective support services for small-scale aquaculture producers. The MFMR should explore the existing communal hierarchical system to collect production statistics from aquaculture farmers.
- To facilitate evidence-informed policymaking and planning for aquaculture development, it is necessary to communicate research and technical evidence to policymakers and planners. The MFMR should take the lead role in preparing concise documents from detailed research and technical reports for policymakers and planners.
- The MFMR should encourage private hatcheries, and the government hatcheries should not compete with them as fry/fingerling suppliers. Shifting the role of government hatcheries as a fish seed supplier to genetic conservation would be more beneficial for the long-term viability of the fish seed industry. Government hatcheries, with support from private hatcheries, should focus on maintaining genetic stocks and broodstock of aquaculture species to overcome the constraints related to genetic quality, such as inbreeding problems and difficulties in breeding some species, faced by small-scale hatcheries because of a lack of pond space and broodstock management capacity (Siriwardena 2007).
- Encourage decentralized seed production and networking for seed supply to reach remote areas through support from GoSL hatcheries and other local government institutions. Giving farmers access to high quality fish seed available at appropriate times for stocking will ensure the smooth flow of products and value along the entire aquaculture value chain.
- Given the fact that most rice farming in IVSs is subsistence done in small rice field plots, integrating rice farming with fish farming should be encouraged as a means of increasing the productivity from unit land area.
- Provide justification for public (and donor) investment in the development of the sector, as well as incentives for private investments in the establishment of aquaculture farms and firms. The GoSL should provide incentives and support for investment in activities along the value chain, such as credit, better market conditions and infrastructure, and assistance in market access.

Recommendations for R&D and academic institutions

- Undertake a fish market and livestock population survey that documents fish prices and livestock populations in Tonkolili and Bombali districts to improve and refine current aquaculture development suitability models at the chiefdom level. The livestock population and fish prices data currently available is only at the district level, so it should not be used in the models at the chiefdom level.
- Undertake quantitative and comparative study of the relationship between the level of local knowledge held by people on fisheries ecology and the tendency to adopt fish farming. In other words, assess the correlation between local technical knowledge on fish and fisheries and the willingness to adopt aquaculture technology in Sierra Leone. This local knowledge should be documented and disseminated.
- Assess the effects of natural predation and other ecological factors on the productivities of fishponds, such as pond depth, distance from the main river or stream, water quality, feed and feeding regimes.
- Conduct long-term studies on fish marketing and distribution in Sierra Leone to fully understand seasonal variations in the demand, supply and price structure of fish in the country.
- Investigate technological innovations to use other fish farming methods and other species, apart from tilapia and catfish, with a view to establishing which species and farming methodologies are more sustainable and financially viable.
- Update the inventory of freshwater fish species and investigate the suitable species to increase the aquaculture species diversity and identify small indigenous species with high nutritional value.
- Develop the practical capacities of research and training institutions (Njala University and Institute of Marine Biology and Oceanography, Fourah Bay College) so that these institutions can produce practical farmers and technicians with hands-on

training facilities and not blackboard and chalk training.

- Allow Njala University to build institute-industry research partnerships with existing and potential farmers to improve quality broodstock, produce quality fingerlings, increase production yields and promote good management practices.
- Channel research support to researchable subjects based on farmer needs (Siriwardena 2007).

Recommendations for fish farmers and producers

- Encourage farmers to culture freshwater catfish and other highly priced species and target the small retail markets in cities in the interior of the country (Bo, Kenema, Makeni) as well as mining areas like Kono, Tonko Fields and Bumbuna, rather than the larger wholesale weekly markets along the main roads in Sierra Leone.
- Encourage fish farmers to use multiple ponds to increase flexibility and to try to synchronize production with periods of high fish demand and low fish supplies.
- Small- and medium-scale businesses should explore possibilities to form partnership ventures in which they can invest in fish farming as a business. They need to adopt new skills and strategies to increase economic returns by organizing and operating as shareholders in a fish farming business.
- Promote changes in land use to a more continuous use pattern in which the same plot of land is cultivated every year by using fertilizers or manure and other agricultural practices that would improve soil fertility without the need to leave the land fallow.
- Encourage farmers to organize themselves so that they deviate from the individual farming practices engaged in the entire lifecycle of fish, from breeding to grow-out, and break up the lifecycle to engage in as fish breeders or fry to fingerling rearers or out-growers.

Recommendations for input suppliers

- Most inputs for aquaculture are not locally available in Sierra Leone, and importing them could be expensive, relative to the per capita income of Sierra Leoneans. Suppliers should look for appropriate technologies in manufacturing inputs using locally available raw materials.
- Check how inputs in the subregion, such as Nigeria and Ghana where environmental conditions are similar to Sierra Leone, are produced and sold to farmers. Suppliers should only import and sell fish feed in Sierra Leone once the demand is justifiable to import feeds, and if they know they can sell at a profit.

Recommendations for FAO and WorldFish

- Assist with a sustainable livelihoods analysis to identify what opportunities are available for poor farmers to enter aquaculture. Developing aquaculture and inland fisheries practices for poverty alleviation and livelihood enhancement and nutrition should be based on a sound understanding of the livelihoods of poor communities and fishers. This is because it is very important to understand who could be involved in aquaculture and inland fisheries as a livelihood. Poorer and remote households usually have limited options to engage in aquaculture, so a spectrum of technologies should be offered according to the resources available for the poor. Sustainable livelihood analyses are primary for alleviating poverty and developing livelihood and nutrition enhancement strategies and interventions because they will provide a better understanding of who are poor, why they are poor and what aquaculture and inland fisheries options would be acceptable to them to make their livelihood sustainable.
- WorldFish and FAO should emphasize training and support research toward the assessment and development of local feeds materials, because current production levels cannot support fish feed imports that commercial producers are using in other countries.
- Facilitate decentralized fish seed supply networks including high market value fish species so that they are domesticated and artificially propagated to promote their cultivation. For example, catfish is also a species of consumption preference just like tilapia, which is currently promoted as the main culture species by government and other development partners.
- FAO, WorldFish and others need to support technology transfer North-South and South-South cooperation by, for example, bringing experts from Nigeria catfish enterprises to support Sierra Leonean farmers.
- Assist in not only strengthening knowledge and skills and changing attitudes and behavior of farmers to become primary producers but also in developing entrepreneurial skills to become successful traders.
- Help develop the skills and capacities of farmers for business development, and run small-scale aquaculture practices as agribusinesses.
- Assist in developing extension material that provides strong management tools for farmers to facilitate their own decision-making and include effective indigenous knowledge for propagation and improvement. It is equally important that

extension material include harmful indigenous knowledge for rejection by farmers.

- Provide assistance to identify gaps and weaknesses in capacities for current and future needs of the sector, and assist in development and training and education programs.
- Seek assistance to identify and characterize weaknesses and inefficiencies along the value chain, and introduce measures to increase the "market power" of producers.
- Help explore opportunities for small-scale farmers to enter into aquaculture based on a sustainable livelihoods approach.
- Assist in developing an R&D program on aquaculture and fisheries for Njala University based on a priority-setting exercise that would enable a systematic approach to priority problems and the better allocation of resources. The program would be sharply targeted at priority problems rather than being diffused by many studies dictated by varying institutional or other preferences.

Recommendations for donors and NGOs

- Design and plan for longer-term support projects because short-term projects often fail since sustainability is not incorporated in the project closure formalities.
- Facilitate access to rural financial services tailored to the specific needs of farmers, and encourage the formation of FBOs so that farmers can share knowledge, skills and market intelligence information but not engage in community fish farming enterprises.
- Incorporate local knowledge and technologies into the development packages that donors support, because this would enhance sustainability after project closure.
- Encourage household and individual approaches in the support given to farmers instead of supporting community fish farms, which always end up being abandoned.
- NGOs should hire qualified aquaculture specialists when they implement aquaculture projects or at least recruit a short-term consultant at the aquaculture technician level—a person who already has commercial experience setting up and running private sector tilapia farms and hatcheries.
- Donors should provide assistance for institutional capacity building in research management. Scientific skills in critical disciplines and fields of research should be provided as well as support for key research areas.
- Donor assistance should be provided to develop and institutionalize a national training program and support the upgrading of local educational programs through capacity building for faculty, instructional materials and laboratories.
- Donor assistance should also be focused on promoting and strengthening trust and cooperation among all players in the value chain.

Harvesting a fishpond in Tonkolili.

Notes

[1] The farming of aquatic organisms, including fish, molluscs, crustaceans and plants. Farming implies human intervention to enhance production (e.g. stocking fish, feeding them or providing protection from predators). Farming also means ownership of the fishstock being cultivated. Aquaculture operations vary greatly from place to place, from rice paddy or freshwater fish farms in Vietnam and saltwater shrimp ponds on Ecuador's coast to netcage salmon operations off the shores of Norway or Scotland. However, most aquaculture occurs in the developing world and involves the production of freshwater fish low on the food chain, such as tilapia or carp (FAO 2017. Accessed 16 August 2017. http://www.fao.org/fishery/collection/glossary_aquaculture/en)

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Annex

Data collected on pond characteristics and GPS coordinates to determine the geographic distribution of existing ponds in Tonkolili and Bombali districts.

1. **Name of farm and owner**

2. **Location**
   Name of village:
   Name chiefdom:
   Name of section:
   Name of district:
   GPS coordinates of the sites:

3. **Time of establishment of the farm/ponds:**
   Month:
   Year:

4. **Ownership of farm/ponds**
   Individual privately owned:
   Group of individuals privately owned:
   Family owned:
   Community owned:
   Leased government land:
   Leased private land:

5. **Water source**
   Stream:
   River:
   Spring:
   Well:
   Floodwater:

6. **Number of ponds in the farm**

1	2	3	4	5	6	7	8	9	10	>10

7. **Dimensions of each pond (m)**

8. **Number and dimensions of ponds in the farm (m)**

Pond	1	2	3	4	5	6	7	8	9	10	>10
Length											
Width											
Depth											

9. **Depth of the pond (without water) (m)**

Pond	1	2	3	4	5	6	7	8	9	10	>10
Depth											

10. Average depth of the water in ponds (m)

<0.5	0.5-1.0	1.1-1.5	1.6-2.0	2.1-2.5	2.6-3.0	3.1-3.5	3.6-4.0	4.1-4.5	>4.5

11. Current use

Operational status:

Pond	1	2	3	4	5	6	7	8	9	10	>10
Operational											
Operational intermittently											
Abandoned											

12. Culture practice

Tilapia culture:
Catfish culture:
Cutlass fish:
Others:

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