UNIVERSITY OF WISCONSIN-STEVENS POINT

International Aquaculture: Past, Present, and Future

Case Studies: Cambodian Sustainable Rice Fish Integration & Namibian Aquaculture

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Aquaculture, the farming of aquatic organisms, has existed in some form for 4000 years. There are various hypotheses of how aquaculture came to be including the Oxbow, Catch-and-Hold, Concentration, and Trap-and-Crop theories. It has evolved from extensive culturing into very intensive. There are a variety of types of aquaculture systems including pond, rice and fish integration, cage culture, raceways, and recirculating systems. The intensification of aquaculture occurred following the Blue Revolution of the 1950's when demand for fish products spiked. This increase in demand occurred due to the understanding of fish health benefits including omega-3 fatty acids and the strive to eat locally.

Poverty alleviation and preservation of wild fisheries are two of the main reasons for the current increase in aquaculture. In developing countries low tropic level fish can be raised using semi-intensive methods at relatively low cost. This provides a consistent form of protein in areas that are nutritionally deficient and have low food security.

The Sustainable Rice Fish Initiative in Cambodia and the WorldFish center Malawian project provide education, outreach, and extension to poor farmers in these countries to aid with implementation of integrated rural aquaculture systems. SRFI focuses on the integration of fish into existing rice paddy production via education through a partnership between Prek Leap National School of Agriculture in Cambodia and the Fisheries and Marine Institute of Memorial University in Newfoundland, Canada. WorldFish Center developed a research and extension program in Malawi and other poor countries that work directly with farmers to build and integrate fish ponds into their current farming practices. Both projects have integration between crop and fish production that uses a cyclic ecosystem approach to alleviate poverty and provide food security.

Aquaculture, the farming of fish and aquatic plants has existed for over 4000 years (Rabanal, 1988). Over those 4000 years of its existence aquaculture has fluctuated in methodologies, species farmed, environmental affects and economics. The present circumstances in aquaculture are more technologically based than ever before. The future of aquaculture is bright due to the trend of depleting of the oceans' fish resources. By understanding the past and education in the present, the future of aquaculture can aid in decreasing the overuse of marine resources and help reduce food shortages for the world's poverty stricken populations.

PAST

The beginning of aquaculture is thought to have arisen between 2000-1000 B.C. in China. There are multiple theories as to how this husbandry technique developed, including the oxbow, catch-and-hold, concentration, and trap-and-crop theories (Rabanal, 1988). The Oxbow Theory reflects nature's natural system of developing oxbow lakes from meandering rivers. As the river changes course, a section may no longer be attached to the main river system, thus a new lake. Oxbows are natural locations for high concentrations of fish due to the yearly stocking by floods. Humans, being naturally entrepreneurial, took advantage of these by enhancing the habitat, making more oxbow areas, and eventually stocking additional fish into existing lakes. According to Rabanal, Bangladesh may have been a good location for this to have developed.

The second theory outlined by Rabanal (1988), is the Catch-and-Hold Theory. This theory focuses on the tendency for nobles to request fish all year round. In order to elicit this, workers would catch wild fish and transport them to neighboring water locations where they could be accessed easily. Many water areas that were artificially constructed for other purposes such as in gardens or defense around a dwelling were stocked with these wild fish. The common carp (*Cyprinus carpio*) is a fish species that would be able to survive and flourish in this type of environment.

The Concentration Theory focuses on environments that have seasonal monsoon periods that inundate the landscape with water, but then the water subsides during dry seasons. The basis of this theory is that as the water subsides, the areas where it stays become concentrated with large populations of fish due to the smaller quantity of water. As time progressed, the humans of the areas began differential harvesting focusing on the larger fish and allowing the smaller fish to grow and reproduce. The depressions that the water stays in were improved for future water catchment and enhanced populations of fish. This theory would likely have developed on the African continent due to the tropical environment and low plains (Rabanal, 1988).

The final theory outlined by Rabanal (1988) is termed the Trap-and-Crop Theory. This theory would have developed in marine locations, especially tidal coastal locations that receive nutrients and flushing with each tidal movement. These areas have natural lagoons that fill with water and organisms during high tide, and maintain a level of water during low tide when the water recedes. This provides the optimal location for an entrepreneurial human to develop an aquaculture system. It is believed that fences and traps were created that allow fish and crustaceans in but not out, allowing easy harvest. Over time there was a switch to allowing the fish that entered the trap to grow to a larger size, thus aquaculture. Areas of southeastern Asia, primarily Indonesia, the Philippines, Thailand, Malaysia, and India have the ideal environment for this theory to have developed.

It is believed that aquaculture started in China due to the population becoming sedentary relatively early in human history (Rabanal, 1988). Another possible reason for the beginning of a traditional practice of aquaculture in China is attributed to the dense population in this area early on that caused the nearby wild fish populations to decline, eliciting the need for other ways to obtain fish and seafood (Edwards, 1999). The first manual on fish culture, “The Classic of Fish Culture,” was written by Fan Lai around 475 B.C. While this was not a manual by current standards, it was the first recorded instance of fish culture. It included descriptions of ponds, methods of propagation, and described the growth of fry. Besides China, many other countries have been participating in aquaculture for a myriad of years. This data is represented on Table 1.

Table 1: Distribution of early aquaculture according to type of culture, adapted from Edwards, 1999 and Rabanal, 1988

Country	Year Began if available	Type of Culture	Species Cultured if applicable
India		Pond	
Laos		Rice/fish combined	
Vietnam		Rice/fish combined	
Java		Pond and Rice/fish	
Cambodia	Last century	Cage	
Indonesia	15th century	Cage	Marine and brackish
Europe		pond	Common carp
Africa		pond	Tilapia, carp, catfish
China	2000 B.C.	pond	carp

PRESENT

Intensification of aquaculture began in the 1970's. The intensification first began in the Asian countries where aquaculture had been traditionally practiced. From there it branched out further into Africa, Europe, and the Americas. Today's aquaculture is separated according to the intensity of the farming technique as extensive, semi-intensive, or intensive. Extensive aquaculture requires the least amount of technology and human intervention. It depends on natural foods like phytoplankton and zooplankton for the cultured fish to feed upon. Semi-intensive systems also focus on natural food, but the concentration of the food in the system is manipulated by humans using fertilizers or low cost feeds. These semi-intensive systems require fewer inputs, but use more land and water than extensive systems. Semi-intensive systems were often used in the past, are currently being utilized and have future advantages as a synergistic system with other agricultural techniques. Intensive aquaculture requires the most starting capital, technology, and education in culturing aquatic species. An intensive aquaculture system is dependent on nutritionally complete specified diets rather than natural foods. These diets can be made from small marine fish that have no other economic value, or formulated from plant materials depending on the species being cultured (Edwards, 1999). Intensification allows more fish to be produced using less land and water, thus is viewed as more sustainable.

The main detriment to aquaculture in present times is the connotation in which it is received in not only developed, but also developing countries. In North America aquaculture is primarily of the intensive variety, where the species cultured are high trophic level carnivorous fish that are highly desired in the markets of U.S. and Canada. Such species include salmon, trout, bass, and yellow perch. These species are difficult to produce and require specialized feeds that focus on high levels of protein. This protein is primarily obtained from small, oceanic forage fish such as the Atlantic Menhaden (*Brevoortia tyrannus*). As described in an article published in the Economist entitled “A New Way to Feed the World,” these species types are the “bad guys,” causing more harm to aquaculture industry and marine resources than help.

Internationally as well as in southern North America, most cultured fish are herbivorous or omnivorous species; carp (*Cyprinus carpio*), tilapia (*Oreochromis*) and catfish (*Pylodictis*). These species feed lower on the trophic level, thus do not depend on an ocean resource (forage fish) for their growth. Other commonly cultured aquatic organisms are scallops, mussels, and oysters which are filter feeders. Filter feeders require even less inputs into an aquaculture system than lower trophic level fish species.

The perceived aquaculture industry is not the most common type of culture, it just happens to be the most profitable. In fact, 80% of aquaculture is the culturing of the lower trophic level fish species and filter feeders. Along these same lines, it is evident that domination of the aquaculture industry has come from developing countries, especially Asian countries that farm these types of species.

According to Halfyard (2010), aquaculture growth is about six times faster in developing countries than developed ones. In 2006, the global wild fishery was stable at 80 million metric tons while aquaculture increased to 59 million metric tons. In 2009, aquaculture provided 50% of the fish consumed globally. The top producing countries were China, India, Vietnam, Thailand, Indonesia, Bangladesh, Chile, Japan, Norway, and the Philippines. In the last two decades aquaculture has doubled in each decade. Fifty percent of this growth has been from China, and has primarily been inland aquaculture production (Halfyard, 2010).

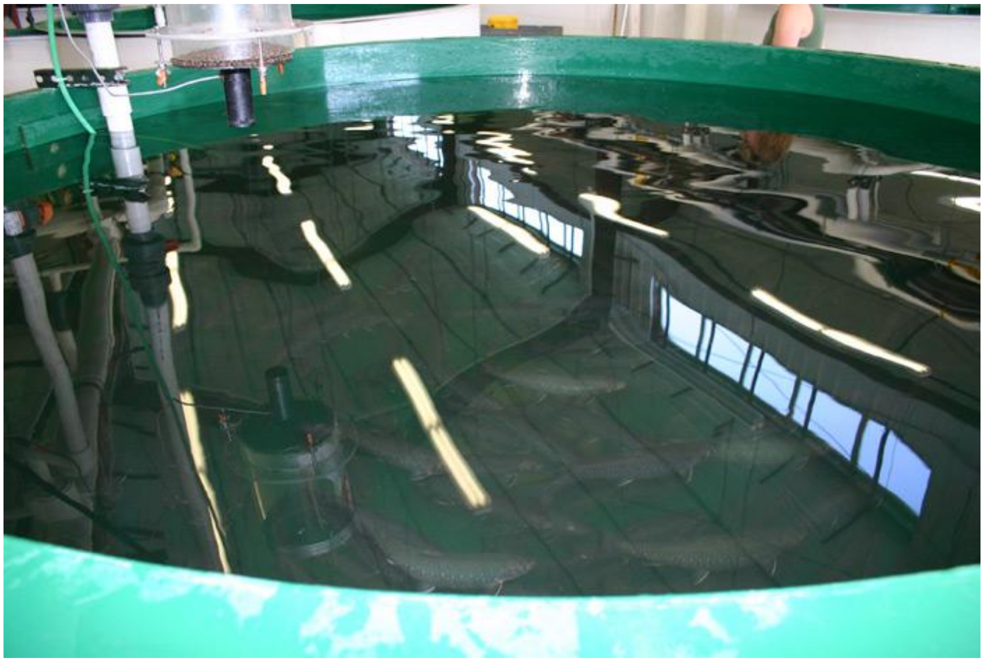
The current buzz phase in aquaculture has been the “Blue Revolution.” The blue revolution developed following the 1950’s when demand for fish products increased by 100%

(Costa-Pierce, 2003). In 2009 the world human consumption of fish was 15-16 kg/person, with Asian consumption being higher than North American and other developed countries. The earth's natural waters had already been fished to capacity, so aquaculture had to and will continue to fill the increased demand needs. This greater demand was met with the before mentioned intensification of aquaculture. This intensification had similar trends to those of the agricultural "Green Revolution"; reducing labor, using automation, and developing selective breeding programs (Halfyard, 2010).

Current aquaculture methodologies were either developed or enhanced in the past 40 years since the blue revolution. All fish culturing has been improved due to a greater understanding of water quality. Aquatic organisms are reliant on water for their survival. Understanding of dissolved oxygen, pH, alkalinity and its buffering capacity, and ammonia wastes has increased the amount of fish that can be raised in a given volume of water due to waste removal and treatment. The epitome of this water quality understanding is the rise of Recirculating Aquaculture Systems (RAS). In RAS systems, the water is nearly 100% reused (normally about 95-99%) through a tank system. The use of settling basins, microorganisms for nitrogen conversion, and UV disinfectant clean the used water to the point at which it can be re-administered to the tank and reused numerous times by the fish. In less intensive systems such as pond or cage culture, technology such as air stones and aerators enhance the dissolved oxygen concentration in the water (necessary for aquatic organisms) and aid in microbial breakdown of the wastes.

Economic and consumer trends have currently been striving for more environmentally friendly product and food types. Another common buzz word is "eat locally." According to Halfyard (2010), North Americans are willing to pay a premium for crops grown or raised within

100 km of the location sold. Information about the benefits of omega-3 fatty acids that are available in fish flesh are well known in the present times and contribute to the demand for these products. For these and many more reasons, the outlook for aquaculture in the future is bright.



FUTURE

There are two basic systems for aquaculture, land based or water based. Land based systems include ponds, rice fields, and RAS systems. Water based systems use existing water bodies along with cages or other enclosures that are constructed for containing or attracting aquatic species. Both these systems provide future opportunities for new people to delve into the aquaculture industry. Water based systems would be especially beneficial for landless people to obtain steady income and food security.

Since its early beginnings in China, semi-intensive fish culture has been paired with other types of agriculture to diversify the crops, and thus decrease risk of crop loss. Poor farmers that already have a pond or rice field on their property can easily stock that water body with small fry that can be obtained for relatively low cost. The technology to raise fish in these environments is of low cost (if is even required to purchase) and relatively easy to learn provided the proper education. As stated in the Edwards article, “addition of fish and other aquatic organisms has been demonstrated to generate income in rural communities” (1999). The benefits of aquaculture for improving the livelihood of the poor include food security, protein food source, employment and income. These systems have been proved to improve the productivity and profitability of small-scale farms (Edwards, 1999).

“Rural aquaculture,” a term having been introduced recently is defined as “the farming of aquatic organisms by small-scale households using mainly extensive and semi-intensive husbandry for household consumption and/or income” (Edwards 1999). Including, and aside from the countries mentioned above, there are opportunities for rural aquaculture to help with poverty alleviation. One such project being led by the Fisheries and Marine Institute of Memorial University called the Cambodian Sustainable Rice Fish Integration (SRFI) Project will be discussed at some length below. This project focuses on the synergistic abilities of raising a plant and fish using the same water.

While poverty alleviation is a noble goal, and well within the sights of the aquaculture industry, the protection of marine resources is a venerable aspiration also. Due to overfishing in attempt to satisfy the growing world population, many marine fisheries have all but collapsed in what can be termed a “Tragedy of the Commons.” The future of aquaculture does not lie with carnivorous, top predator fish such as salmon or trout, it lies with sustainably grown herbivorous, omnivorous, or filter feeding organisms. As was very eloquently stated by Halfyard (2010), “land conflicts were and are the causes of wars, while the future is expected to see wars over freshwater and oceanic resources.”

CASE STUDIES

SUSTAINABLE RICE FISH INTEGRATION PROJECT

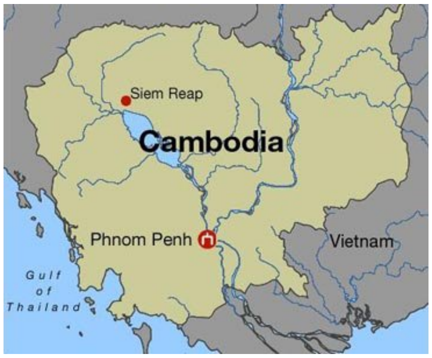
The Sustainable Rice Fish Integration (SRFI) project is an example of how aquaculture could be utilized to alleviate poverty in a developing country. The SRFI is a project based in Cambodia that is a pairing between the Prek Leap National School of Agriculture in Cambodia and the Fisheries and Marine Institute of Memorial University (MI) in Newfoundland, Canada. The primary purpose for this project was to "decrease the incidence of extreme hunger and poverty and empower women by promoting gender equality, with a subsequent impact of improving overall health" (ACCC, 2006). Cambodia was chosen for the SRFI project due to its high levels of poverty and lack of food security.

Country Background

Cambodia is one of the poorest countries in the world, 35% of the population is below the poverty line, and it is 130th out of 177 on the Human Development Index (Halfyard, 2010). The risk of infectious disease is very high, with a large percentage of those being food and waterborne diseases such as bacterial and protozoal diarrhea, hepatitis A, and typhoid fever (World Factbook, 2012). There is a discrepancy between genders in Cambodia, with males having a more dominate role traditionally. Men have dominated in fish culture, educational activities, and decision making. Women are traditionally in charge of rice labor and household activities and receive little training (PNSA, 2012). In terms of literacy, this gender discrepancy can be quantitatively illustrated; 84.7% of males are literate, whereas only 64.1% of females are (World Factbook, 2012). As a whole, the population lacks education and productive skills. This is highly prevalent in the rural areas which are particularly poverty stricken and have little infrastructure.

Project Goals

Prek Leap National School of Agriculture (PNSA) is a continuing education and training center in Phnom Penh, the capital city of Cambodia. It was developed to provide the education and productive skills that are needed for the large young population of Cambodia. The purpose of PNSA is:



> *"The continuing education program provides opportunity to various students and officials and staff from government, private sectors and nongovernmental organization to build capacity and gain experience on agriculture and related specialization for various degrees namely certificate of training, associate degree and bachelor degree. The qualification and experience from the applied courses will effectively contribute to poverty reduction and to enhance rural livelihood in Cambodia"* (PNSA, 2012).

The collaboration with MI on the Sustainable Rice Fish Integration project is intended to increase the training of rural farmers that are in desperate need of educational improvements due to the high levels of poverty. Government involvement between both countries has focused on reducing the poverty of individual communities by providing rice and fish security through the educational program.

The pilot project was conducted from 2006 through 2010 in the Takeo province of Cambodia. Takeo province was chosen for this project for the following reasons: it has food

shortages during the dry season, a documented need for training of farmers, no government agencies that were operating in the region that conflicted with the aims of the project, and the area was new to this particular training. While the overall goal of the project was to reduce poverty in rural areas in Cambodia via the education of sustainable rice fish integration, the specific purpose of the pilot project was to help the PNSA with their programs in sustainable rice fish integration (ACCC, 2006). The expected outcomes included a more effective training program to the rural farmers, increased gender awareness, and more women involved in agriculture, among other outcomes. The expected impacts were enhanced food security in the region and livelihoods of women improved.

Environmental Impacts

The scientific basis behind this project stems from the idea that integrating rice and fish culture will lead to less resources being used while resulting in more food production. This is, as was discussed above, in relation to semi-intensive fish culture and the diversification of crops. In Cambodia it is common practice to use chemical fertilizers on the second yearly plantings of rice to increase the crop yield (Ministry of Commerce and UNDP Cambodia Trade Project, 2010). The use of these fertilizers is considered to lower the quality of the rice crop grown using chemical fertilizers when compared to organically grown rice. It is even common practice for the farmers to keep the organically grown rice for their personal consumption and to sell the lower quality rice for profit. This often leads to a profit deficit. Nitrogen fertilizers are considerably expensive and this initial cost is not always covered by the lower profit for chemically fertilized rice. Implementing an integrated fish-rice culture would provide natural fertilization for the rice and negate the need for chemical fertilizers. Not only would this improve the profit from the rice, it would also provide added income from the sale of the fish. Revenue from the fish could even surpass that of the rice production, studies show (Ministry of Commerce and UNDP Cambodia Trade Project, 2010). Environmentally, it is also beneficial because the need for pesticides is eliminated due to the fish feeding on insects.

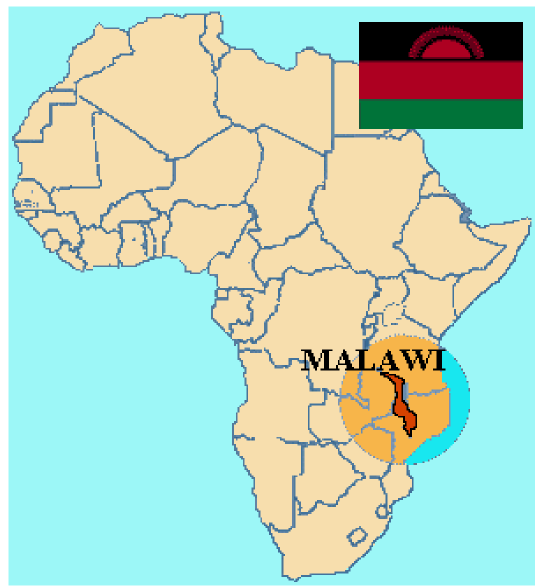
Summary and Future

The SRFI project has found that integrating rice fish operations increases the annual yield of rice and fish, increases the health, income, and food security of people participating in the project, and is environmentally sustainable when utilized correctly. It exemplifies the idea of "rural aquaculture." The fish raised are intended to be consumed by the farmer or sold locally for increased income. The focus of this project on including women in the education is an added benefit. The SRFI aims to help Cambodia reach the Millennium Development Goals (United Nations) to reduce poverty by 2015 (PNSA, 2012).

MALAWIAN AQUACULTURE

The WorldFish Center has been conducting research regarding the potential of areas to invest in aquaculture in order to reduce poverty and hunger. The four countries that fall under this research umbrella include Bangladesh, Cameroon, China, and Malawi. The focus of this particular case study in Malawi, a land locked country in Southern Africa.

Country Background



According to FAO, Malawi is one of the poorest countries in Southern Africa and is ranked 153 out of 169 on the Human Development Index (FAO). The population of Malawi is 15.7 million, the majority of which (52%) live below the poverty line. Of this 15.7 million, 3.9 million are undernourished, which is 28% of Malawi's population. The life expectancy is only 53 years. Malawi also has a high level of HIV/AIDS, with 480,000-1,400,000 people being directly affected (Russell et al., 2008).

The main economic activity in Malawi is agriculture, with the big players being tobacco, sugarcane, cotton and tea. Eighty percent of the land area is used for agriculture (FAO). Historically, fish is a huge part of the Malawians protein diet, about 70%. Being a landlocked country, this fish production came from inland lakes and rivers, primarily Lake Malawi. Due to overfishing, drought, and population growth the fish populations in these inland waters have declined greatly. Now only about 28% of Malawians protein is attributed to fish.

Project Goals

The main focus of this particular WorldFish Center project was to identify the opportunity for aquaculture development and growth in Malawi to decrease the overall poverty of the country. In such a poor country with a high rate of HIV/AIDS, it is important to have reliable and cheap protein availability. Since the initiation of the Presidential Initiative on Aquaculture Development (PIAD) in Malawi in 2006, there has been a greater push for aquaculture and better aquaculture practices. With the help of many various NGO's pond aquaculture is often adopted as an integrated component of food security programs. The combined strategies of these initiatives are as follows:

Table 2. Strategies of integration food security program from Russell et al. 2008

Themes	Current situation	Strategies
Strategic Theme 1 Integration of aquaculture into rural livelihoods	Contribution by aquaculture to sustainable livelihoods is limited.	1. Providing the opportunity for all stakeholders to develop their capacity to enhance the integrated livelihoods approach, which includes aquaculture
Strategic Theme 2 Enhanced economic opportunity for commercial fish farmers	There are no small-scale dedicated fish farmers in Malawi.	2. Enhancing institutional capacity of NAC to develop medium- to large-scale commercial fish farming technologies
	There are two emerging large-scale commercial aquaculture operations.	3. Providing an appropriate credit, business training and technology package for small and medium-scale commercial fish farmers
		4. Creating a regionally competitive and investor-friendly environment through a sound policy, clear procedure and legal framework
		5. Ensuring aquaculture activities are environmentally responsible and sustainable
		6. Establishing links and information flows between producers and fish traders to enhance access to markets
Strategic Theme 3 Competent local government, NGOs and producer organizations	Low levels of recognition and poor technical skills relating to aquaculture in local government and NGOs	7. Sensitizing and building the capacity of local government on their primary responsibilities in aquaculture development
		8. Developing alliances between DoF and NGOs to promote unified approaches in aquaculture extension
		9. Fostering fish producers' organizations that help farmers increase production and access financing, markets and services
Strategic Theme 4 Smart and practical DoF	Ineffective and inefficient service delivery by the DoF	10. Building healthy DoF financial resource
		11. Realizing efficient DoF operation
		12. Promoting quality DoF staff and information

DoF = Department of Fisheries, NAC = National Aquaculture Centre, NASP = National Aquaculture Strategic Plan, NGO = nongovernmental organization.

Source: System Science Consultants Inc. 2005.

The WorldFish Center, formerly known as the International Center for Living Aquatic Resources Management (ICLARM), is an international, non-profit research organization whose mission is “to reduce poverty and hunger by improving fisheries and aquaculture” (WorldFish Center, 2012). Some of the WorldFish objectives are as follows (WorldFish Center, 2012):

- Improve the livelihoods of those who are especially poor and vulnerable in places where fisheries and aquaculture can make a difference.
- Achieve large scale, environmentally sustainable increases in supply and access to fish at affordable prices for poor consumers in developing countries

Recent studies by WorldFish on the development of village aquaculture ecosystems have shown great opportunity for the future. The village aquaculture ecosystems integrate fishponds in small landholder farms. Most small farms in Malawi and most of southern Africa have some combination of maize, vegetables, rice, fruit trees, and livestock. Fish can be easily integrated into this system using earthen ponds that are cheap to construct within the vegetable gardens. This decreases the amount of work required to transport the fish food (garden waste) to and into the ponds. It has become common practice for the ponds to be constructed in low areas in farmers’ fields where the maize or vegetable crop was often low yielding due to water logging. These ponds easily fill by rain and/or groundwater. The following schematic illustrates how fish can be integrated into a Malawian farm.

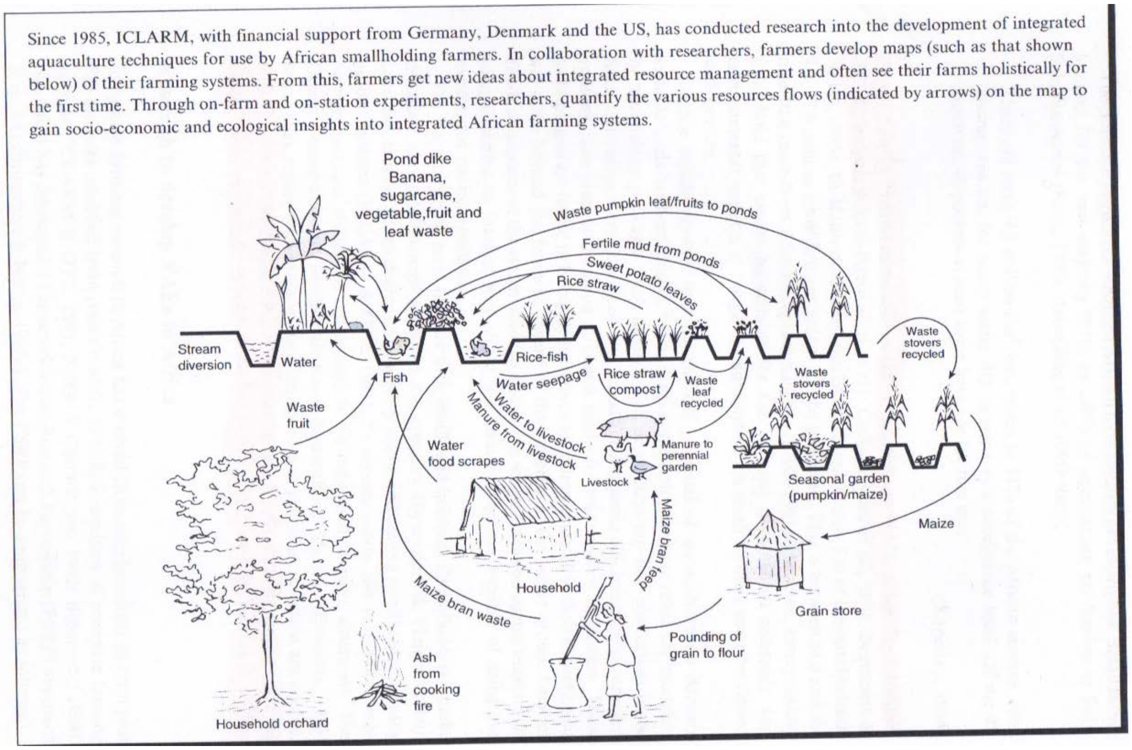


Figure 1. Integration of fish into a typical farm scenario in Malawi. Brummett and Costa-Pierce 2002

Environmental Impacts

Integrated fish farms, like those illustrated above, have a very small ecological footprint in comparison to other methods of fish production and capture. To support 1 m^2 of tilapia using cage culture was found to have a 21,700 m^2 ecological footprint when water area for fishmeal, land for grain (for fish food), and water for oxygen and nutrients were factored in. For that same 1 m^2 of waste-fed integrated fish the ecological footprint was found to be 1.8 m^2 (Brummett and Costa-Pierce, 2002). For the integrated system the oxygen production and nutrient assimilation is sustained within the pond due to a low density of fish.

Aside from ecological footprint, the integrated system in environmentally friendly because it utilizes waste from the vegetable garden, household, fire ashes, and maize production. Without this use for these wastes they would either be burned or land-filled on the farm property. The integrated system is a good cyclic use of farm products and makes the overall farm more productive, not just enhancing productivity by adding fish, but by aiding in productivity of all farm endeavors.

Summary and Results

The WorldFish study found various positive results of integrated village aquaculture systems. Farms with integrated systems yield between 1000 to 3000 kg/ha/year of fish (Brummett and Costa-Pierce, 2002). Integrated farmers produce near to six times as much profit as a typical Malawian farmer. In fact, the integrated vegetable-fish section contributes about 72% of the cash income of the farmer.

In drought years integrated systems have a profound effect on the food security of those people using these aquaculture systems. During the drought years of 1991 to 1995 in Malawi, maize crops failed and all farmers had economic losses. Those farmers that had the pond-vegetable systems had a reliable source of water that they could use for some crops and maintain some profit. The net cash income to a group of integrated farmers was 18% higher than a non-integrated farmer for a year of severe drought (Brummett and Costa-Pierce, 2002). In such a severely poor country, 18% can go a long way towards helping a family survive and have better food security.

The study also found an interesting flow of information regarding village aquaculture systems. Part of the research involved conducting demonstrations of integrated systems and following up with how much technology farmers then implemented on their farm. Of the 34 farmers that the extension agents worked with directly, 86% had adopted at least one technology, 76% at least two, and 24% had adopted four different technologies (Brummett and Costa-Pierce, 2002). Once these technologies were implemented the knowledge traveled quickly throughout communities. Within 6 months of a demonstration, 46% of those using integrated systems had developed them from knowledge and observation of other farmers. From those initial 34 farmers, after four years, 225 farmers had implemented and were practicing the integrated aquaculture systems to great success.

The continuation of these integrated systems in Malawi has great potential for helping the impoverished farmers. The development of these systems requires little outside help aside from initial demonstrations and education to notify people of this potential option. The assistance of NGO’s with education and aid for initial technology acquisition and implementation would be of great help. Many FAO projects follow along these lines. While it was found that most fish produced in Malawi using the integrated system were consumed by the farmer or the local community, the fish can also be sold for a profit as there is a market for fish in urban areas.

CRITIQUE

The countries in the case studies are both extremely impoverished in their regions. Both countries have a large portion of the population engaged in agriculture. Aquaculture is growing in both countries, but it has a capacity to grow much more.

As discussed in depth above, “rural aquaculture” is the farming of aquatic organisms by small-scale households using extensive and semi-intensive husbandry for household consumption and income (Edwards, 1999). Development of rural aquaculture has great potential to aid with poverty alleviation. This was the impetus of both the Sustainable Rice Fish Integration and the WorldFish Center Malawian project. Both countries could greatly benefit from aid with food, but these projects are following the motto “give a man a fish, he eats for a day; teach a man to fish he eats for a lifetime.” In this case, instead of teaching a man to fish, they are teaching men and women how to raise fish in environmentally friendly, economical ways so they can eat for their lifetime.

In both case studies it is apparent that the most advantageous technique of aquaculture to implement is an integrated system of extensive culture. While in developed countries it is economically feasible to have intensive recirculating aquaculture systems, in developing countries the initial startup cost would be too overwhelming. Integrated systems such as the rice-fish and vegetable-pond scenarios allow poor farmers to basically just dig a pond (or outfit a rice paddy); add fish and they have another form of protein and potentially profitable product. Integrated systems are also the most environmentally friendly option because they use wastes from other crop production. Anything that can be conducted in a cyclic format is typically the most environmentally friendly option.

The impacts of the SRFI project have not yet been analyzed on a large scale because the pilot project was first completed in 2010, but some results have been analyzed from the Malawian project. Brummett and Costa-Pierce (2002) have identified the key components to a sustainable rural aquaculture system development in southern Africa.

" - Bottom up development planning: knowing the socio-economic, gender, and cultural context of farming households and the national policies that affect them first, before any interventions.

- Information transfer: simple messages for farmers generated by research in dynamic consultation with extension

- Sustained adoption: full participation of farmers in the research and development process.

- Ecological evolvability: incorporating and utilizing an ecosystems vision of the farm.

- Economic evolvability: incremental, evolutionary increases in cash productivity to overcome recurrent cash-flow constraints."

Aside from these important components, Brummett and Costa-Pierce (2002) also described how technology "packages" where the farmer needs all components of the system for proper operation of farm aquaculture do not work. These packages are often too expensive and complex for farmers to implement into their farms where they are more concerned about subsistence than turning a profit. For future projects such as this it is crucial that

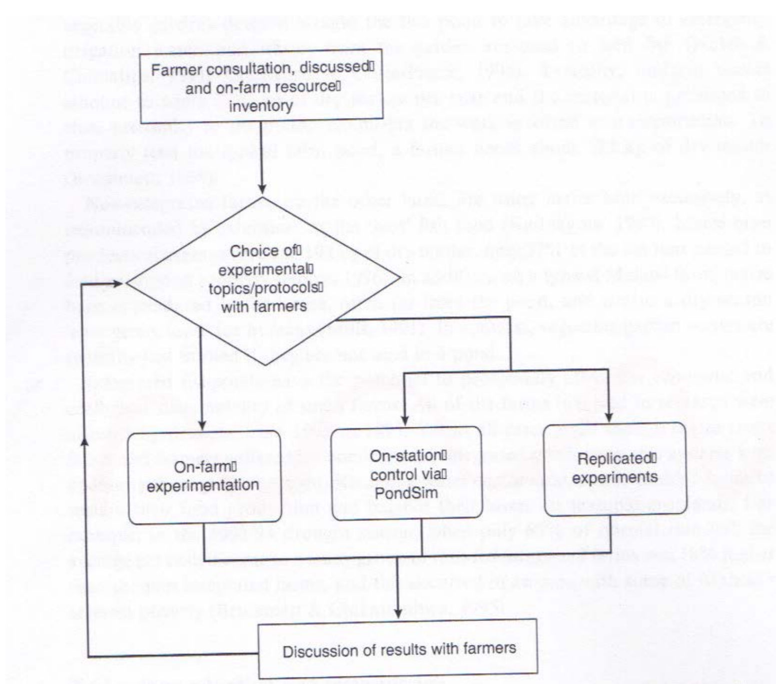


Figure 2. Technique to implement aquaculture technologies in Malawian farms. Brummett and Costa-Pierce 2002.

the education and technology available to the farmers follows a process similar to the flowchart shown above. This allows the system to be tailored directly to the farm and farmer's needs, thus resulting in a better chance for its continued success.

Failures identified in the Malawian project, and other similar projects, stem from extension and outreach failure. The people who have the correct background in aquaculture systems and have the knowledge and ability to educate the farmers correctly on which system would be the most beneficial for them are often not the people doing the extension and outreach. This stems from the fact that most people with the correct background and experience are higher up in organizations and are not in the field. The FAO has identified this same problem in many of their projects and was discussed at the FAO Technical Consultation in the mid 1990's (Brummett and Costa-Pierce, 2002). Some suggestions for alleviating this problem are:

"- Research should provide a promotion facility which interacts with extension to analyze information coming from the field, and experiment stations to find good matches between needs and possible solutions

- To reach large numbers of farmers, a simplified technology should be translated into an extension message which extension and farmers can easily understand

- Extension materials should be generated by researchers and directed at farmers rather than extension agents

- Based on their field experience, extension agents should provide at least initial critical review of the relevance of technologies proposed by scientists."

These suggestions should be kept in mind for the SRFI project. The rice-fish integration does not require much technology, so that is not of importance, but the mode of education is. The Prek Leap National School should make sure that the education employed caters to the farmers themselves and their particular needs.

Overall, both projects seem to have good methods for reducing poverty using aquaculture in an integrated system. They both have taken into account the prior forms of subsistence in the regions they are working in and have tailored the aquaculture design to that.

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