Impact of Development and Dissemination of Integrated Aquaculture-Agriculture (IAA) Technologies in Malawi

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Abstract

Malawi is a small but densely populated country in Southern Africa. Fish is an important part of the nutrition of Malawians, providing essential protein and micronutrients. However, per capita fish consumption has halved over the ten-year period between 1988 to 1998 due to over-fishing in the lakes and doubling of the population since the 1970s, accompanied by an increase in the price of fish. This has worsened access to food insecurity, especially in rural areas, in a country where an estimated 66 per cent of the population consume less than the minimum daily calorie requirement. This paper presents an ex-post impact assessment of the development and dissemination of small-scale integrated aquaculture-agriculture technologies by The WorldFish Center and its national and international partners over more than 15 years in Malawi. The impact study measures the effects of these outputs on the degree of integrated aquaculture-agriculture (IAA) technology adoption and diffusion, the effects on farm income and health of household members, and the welfare effects of increased fish supply on the Malawian economy.

Introduction

Malawi is a small but densely populated country in southern Africa. The major source of income for rural households is agriculture (64 per cent), but landholdings are small and land productivity is generally low. The major constraints on land productivity include lack of irrigation (predominantly rain-fed agriculture) and environmental degradation. The options to intensify agriculture by means of external inputs (such as new varieties, fertilizers and pesticides) are limited as only a few smallholder farmers sell their produce with profit and credit is generally unavailable to farmers.

Fish is an important part of the nutrition of Malawians, providing essential protein and micronutrients. However, due to overfishing in the lakes and doubling of the population since the 1970s, per capita annual fish consumption has decreased from14 kg in 1988 to half that figure in 1998, with a corresponding increase in the price of fish. This has further worsened access food, to especially in rural areas, in a country where an estimated 66 per cent of the population consumes less than the minimum daily calorie requirement (Jamu and Chimatiro 2004).

The Fisheries Department of Malawi designated aquaculture to play a complementary role to the capture fisheries sub-sector (ICLARM and GTZ 1991). Aquaculture increases fish supply and hence reduces the pressure on capture fisheries.

Over the last few decades, several donor organizations have tried to introduce aquaculture to rural farmers in Malawi. However, these projects showed little success as farmers discontinued fish production as soon as subsidies were terminated. Furthermore, there was no diffusion of the technology outside the project areas.

With the objective of generating an appropriate and sustainable aquaculture technology for smallholder rural farmers, The WorldFish Center,[1] in collaboration with the Malawi Department of Fisheries and with funding from the German BMZ/GTZ (Federal Ministry for Economic Cooperation and Development/ German Agency for Technical Cooperation), started aquaculture research in Malawi in 1986. Box 1 provides an overview of the major milestones and key research outputs. The WorldFish Center applied a

[1] Prior to 2002, The WorldFish Center was known as the International Center for Living Aquatic Resources Management (ICLARM).

Box 1. Description of the research by the WorldFish Center and partners in Malawi that led to the technical innovation.

Phase 1 (1986-1990): The WorldFish Center, in collaboration with the Malawi Government and the University of Malawi, conducted a broad range of biological, socio-economic and interdisciplinary research to develop aquaculture technologies and to integrate these into low-input farming systems in the country (ICLARM and GTZ 1991). On-station studies were carried out at the Malawi National Aquaculture Center (NAC) in Domasi to devise management strategies based on locally available resources. A basket of technologies for fish production within an IAA system context suitable for small-scale farming was developed. Extension personnel disseminated these technologies to farmers through the concurrently operating, bilateral Malawi-German Fisheries and Aquaculture Development (MAGFAD) project. Technology adoption by smallholders, however, did not meet aspirations.

Phase 2 (1991-1994): The WorldFish Center moved away from the classical top-down dissemination of technology to a new approach for aquaculture technology development through on-farm experimentation (Lightfoot et al. 1993; Lightfoot and Noble 1993) and transfer that was based on farmer-scientist research partnerships (FSRP). The approach utilized the prevailing resource base and considered constraints faced by farmers to establish an incremental process of adoption steps, in which the technology changes were individual farmer-approved and farm-specific (Brummett and Noble 1995; Brummett and Costa-Pierce 2002; Brummett 2002). The relationship established with the farming community also facilitated the collection of longer-term monitoring data on technology adoption and impact, using the RESTORE tool (Lightfoot et al. 2000).

Major milestones of IAA research by The WorldFish Center and its partners:

Year	Major milestone
1988	Understanding of the agro-ecological and socio-economic environments in which Malawian small-scale farmers live.
1988-1990	Development of the integrated resource management concept, which refers to the synergistic movement and utilization of resources between and among farm and household enterprises. Assessment of local availability of potentially useful bio-resources and their efficiency as pond inputs. On-station testing of IAA technologies. Demonstration of the impact of IAA through farmer-managed on-farm trials.
1991	Wide adoption of integrated rice-fish technology in the Zomba district.
1991-94	On-farm testing of IAA technologies. Development of the FSRP approach to aquaculture technology development and dissemination utilizing RESTORE through Research-Extension Teams (RETs). 2000 Incorporation of the FSRP approach into the National Fisheries and Aquaculture Policy.
2003-04	The aquaculture sector benefited from the Highly Indebted Poor Countries initiative funds that were allocated for the construction of fishponds for poor female-headed households. The funds paid for locally supplied labor. About 751 fishponds were constructed in 2003 with an individual area ranging from 300 m^2 to 400 m^2.

new Farmer Participatory Research approach, in which the potential for farmers to add an additional enterprise to their farms through fish farming was assessed.

This approach, termed RESTORE (Research Tools for Natural Resource Management, Monitoring and Evaluation), is a combination of farmer-participatory field procedures and an analytical database (Lightfoot et al. 2000). The approach involves the use of integrated aquaculture-agriculture (IAA) in which existing resources (in the form of organic wastes and byproducts) on and around the farm are utilized as much as possible as nutrient inputs to the pond and also to other enterprises, leading to more environmentally sound farming systems (Lightfoot et al. 1993; Lightfoot and Noble 2001).

It was implemented by Research Extension Teams (RETs) under the Farmer-Scientist Research Partnership (FSRP) concept (Brummett and Noble 1995; Brummett 2002). The adoption of IAA technologies enhances the sustainability and productivity of farming systems through resource recycling and use of pond water and nutrients for growing agricultural crops (Chimatiro and Scholz 1995; Brummett and Costa-Pierce 2002).

The outputs of The WorldFish Center's project in Malawi are twofold: (i) generation of integrated aquaculture-agriculture production technologies and (ii) development of a technology transfer approach for aquaculture in small-scale farming in Africa.

This paper presents an ex-post impact assessment of the development and dissemination of small-scale integrated aquaculture-agriculture technologies by The WorldFish Center and its national and international partners over more than 15 years in Malawi. The impact study measures the effects of these project outputs

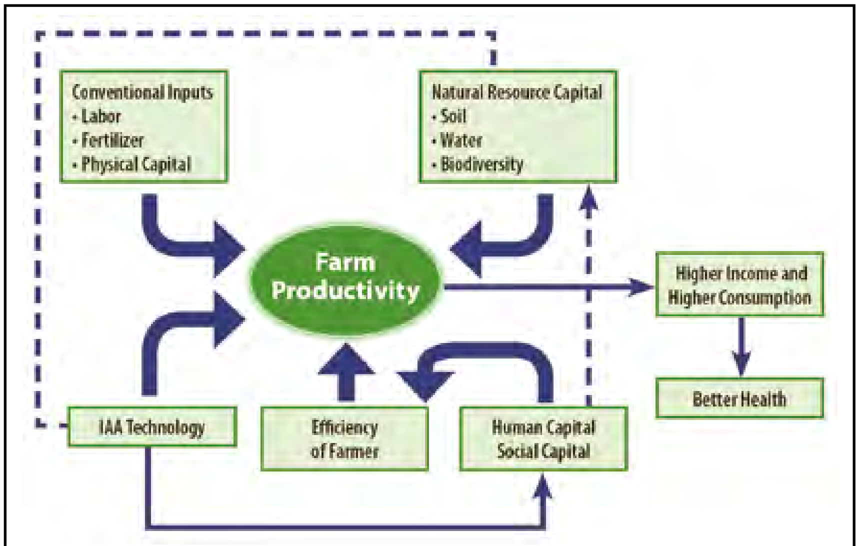

Figure 1. Schematic diagram of farm productivity and household welfare.

Study team interviewing farmers at a field site in Mwanze, Malawi.

on the degree of IAA technology adoption and diffusion, the effects on farm income and health of household members and the welfare effects of increased fish supply on the Malawian economy.

Impact Assessment Framework

The study rests on the overall hypothesis that IAA leads to improved farm productivity. This is because firstly IAA offers a set of technologies in which conventional inputs such as labor, organic fertilizer and capital can be used more effectively. Secondly, IAA improves human and social capital, thus increasing farmers' efficiency and improving the use of natural resource capital, such as soil, water and biodiversity. Improvements in human and social capital result from learning new input use techniques via extension or technology transfer between farmers. Finally, IAA offers farmers an opportunity to increase utilization of biodiversity. In this way, through the improved use of natural capital and other inputs, farmers are likely to increase their productivity (Fig. 1).

This results in households realizing higher incomes and higher consumption, which lead to better health. From this, the following hypotheses can be drawn:

- An IAA household as compared to a non-IAA household is likely to have
  - higher farm productivity,
  - greater technical efficiency,
  - greater human capital.
- Higher human capital and social capital result in higher efficiency of farmers.
- Increased farm productivity leads to higher household income and higher consumption.
- Higher income and higher consumption leads to better household health.

Thus, it is of interest to determine which factors facilitate the adoption of the IAA technology and which factors bring about improved productivity and, therefore, lead to an improved health status. A two-stage framework was used for this ex-post impact assessment of IAA research in Malawi. Stage one identified factors determining adoption of IAA and thus established which technical, socio-economic, institutional and policy factors can be associated with its successful adoption. In stage two, the effect of IAA adoption on efficiency, food security, employment, and sustainability of farming systems was assessed.

The welfare impact of the IAA technologies on producers and consumers at the national level was estimated using standard economic surplus techniques. In addition, the Internal Rate of Return (IRR) of investment in IAA research and development was estimated. Small-scale farm households that, in principle, could have but chose not to adopt IAA technology, were used as the basis for comparison (counterfactual).

Data were collected in early 2004 through a survey of IAA-adopting and non-adopting farmers at six sites in Malawi. At each of the six study sites, 30 IAA and 30 non-IAA (i.e., 'control') respondents were selected representing agro-ecological conditions with a good potential for fish farming and typical socio-economic conditions for rural Malawi. Out of 360 sample farmers, 315 were available for interview. Additional data sources used included monitoring data from a small sample of farmer project participants and a household health survey of 545 respondents including IAA and non-IAA farms.

The analysis applied a comprehensive impact assessment framework and included an adoption study. Impact pathways were explored based on land use changes, input use efficiency, total factor productivity, farm profitability and farm income. To describe the adoption process, a two-stage adoption model was used. The first step captured the adoption decision and the second one the intensity of adoption as measured by the integration level of aquaculture with other farm enterprises. Land use changes were measured by using frequency statistics. To account for the multi-output multi-input setting of the IAA system the concept of interspatial total factor productivity was applied. Profitability was compared using descriptive statistics, while the income effects of IAA adoption were measured by applying econometric procedures (Dey et al. 2006). In addition, a stochastic production and technical efficiency function was estimated that could provide some indication of the IAA technology transfer approach on the technical efficiency of input use.

At the household level, descriptive statistics and parametric tests were used to assess the impact of IAA adoption on the food consumption pattern and the household's nutritional status. The welfare effects of the project on the Malawian economy were estimated by calculating the economic surplus using a multi-commodity model. The increase in consumer and producer surplus was used as a measure of gross benefit. Accounting for the research and development (R&D) investment and taking into consideration the effect of other aquaculture projects on fish output, the internal rate of return was calculated. The quantitative analysis was further complemented by case studies reporting on the success of individual adopters.

Box 2. Summary of farm level impacts of IAA adoption in Malawi.

- IAA farmers grow more high value crops (e.g., vegetables) around their fishponds.
- Total factor productivity of IAA adopters exceeds those of non-adopters by 11 per cent.
- Labor input of IAA adopters exceeds those of non-adopters by 25 per cent.
- Average farm profits per unit area owned by IAA adopters are more than double those of non-adopters.
- Net farm income of IAA adopters exceeds those of non-adopters by 60 per cent.
- Fish accounts for slightly more than 10 per cent of net farm income of IAA adopters.
- An increase of 1 per cent in the probability of IAA adoption increases net farm income per ha by 0.9 per cent.
- Farm size has a negative corelation with net farm income per ha positive corelation with the IAA adoption decision, i.e., larger farmers are more likely to adopt IAA.
- IAA adopters are technically more efficient than non-adopters.
- IAA adopters consume more animal protein than non-adopters.
- No significant impact of IAA adoption on the nutritional status of children below five years could be demonstrated. However, this may be shown in the longer term.
- Case studies revealed that IAA reduces nitrogen loss, increases nitrogen use efficiency and has a positive effect on sustainability.

View of farm with vegetable plots adjacent to fish ponds in Thyolo district.

Adoption

The use of IAA as a strategy to promote the development of aquaculture in Malawi has resulted in sustained increases in fish production from small farms. When The WorldFish Center started its operations in Malawi in 1986, the total annual fish production from all fishponds combined was around 90 t per year. The total fish production from fishponds has currently (in 2005) increased to around 1 000 t per year.

Aquaculture production in Malawi increased at an average annual rate of

7.36 per cent during the period 1970-2001. Much of the increase can be attributed to the dissemination of IAA since 1995. During the phase from 1986 to 1995, i.e., the period when basic research and on-farm trials on IAA technologies were conducted, the annual growth rate was 2.4 per cent. However, after the dissemination of technology (i.e., the years from 1996 to 2001), the annual rate of increase of production was 22 per cent (Dey et al. 2006).

Results of the adoption model analyses showed that the decision to adopt IAA was influenced by several factors: (i) access to extension; (ii) the intensity of IAA training; (iii) endowment with land; and (iv) farmer age. Conversely, the degree of aquaculture integration, which could also be a measure of the success of the participatory technology transfer concept, was found to be influenced by: (i) irrigation access; (ii) gender; (iii) educational attainment of the household head; and (iv) endowment with land. Hence, the adoption decision is influenced by the project variables, but the level of aquaculture integration is driven by factors external to the project's transfer concept. While the analysis provided a good understanding of the adoption process; no exact data on the scale of adoption were available. Hence, the total number of IAA practitioners and what proportion of aquaculture production can be attributed to IAA had to be assumed. Also, no data were available on the uptake of the technology by other development organizations in Malawi and in neighboring countries, although it was reported that these effects exist.

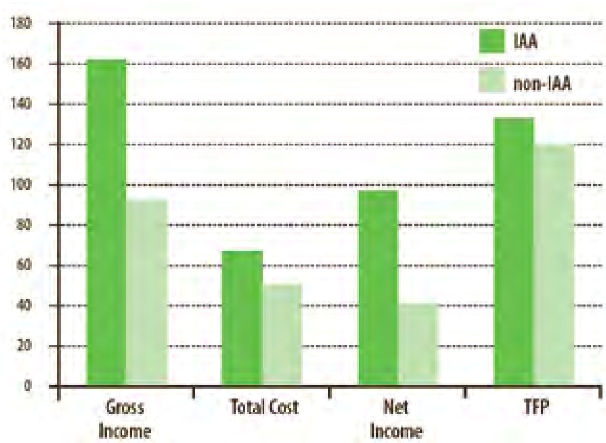

Figure 2. Profitability and productivity from farming activities in IAA and non-IAA households in Malawi. The Total Factor Productivity (TFP) index value is 1.33 for IAA farmers and 1.20 for non-IAA farmers.

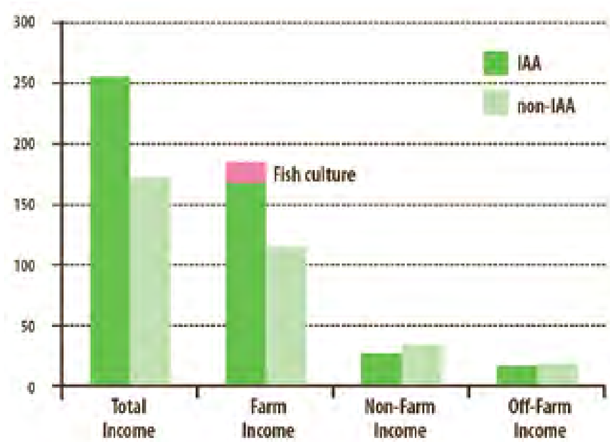

Figure 3. Household income among IAA and non-IAA households in Malawi. Income from fish culture was US$21/year.

Farm Level Impacts

Income from Farming Activities

Our study of IAA adoption in Malawi found a range of farm level impacts (Box 2). The two major constraints to crop production on smallholder farms in Malawi, low soil fertility and water availability, are to some extent overcome in IAA systems through the role of fish ponds in nutrient recycling and water storage. One of the reasons for the higher income among IAA farmers is the increased cropping intensity (due to increased cultivation of vegetables and other crops). There is a positive association between productivity and profitability, and the level of integration, i.e., productivity and profitability increase as the level of integration increases (Fig. 2).

Total Household Income

The total household income was almost 1.5 times higher for the IAA farmers (average US$254) compared to the non-IAA farmers' average income of US$174 (Fig. 3). This difference is mainly due to the difference in farm income (income earned from farming activities) and larger farm size among IAA farmers, IAA farmers had an average farm income of US$185, which is 1.8 times as much as non-IAA farmers' average of US$115. Around 80 per cent of the total income of the IAA farmers was derived from farming, compared to only 66 per cent of the total income of non-IAA farmers. Out of the farm income of IAA farmers, an average of US$21 (about 10 per cent) is directly contributed by fish culture (Fig. 3).

Non-IAA respondents, however, had a higher off-farm income (earned from outside the homestead, e.g., employment or piecework) and more income from non-farm activities (e.g., business within the homestead), though the difference is not statistically significant. IAA practices may require a higher labor input, particularly in initial pond construction. IAA adopters sell less labor (and earn less non-farm income) than non-IAA respondents. The higher off-farm incomes were generally from the sale of labor, and lower for IAA adopters, who invested higher labor amounts on their farm (Box 3).

Box 3. Benefits of on-farm labor use in IAA Activities

IAA farmers use more family labor on-farm than non-IAA farmers. As the productivity of family labor in IAA activities is higher than through alternative opportunities of selling family labor for off-farm activities, the overall return to labor from IAA is higher. Therefore, though non-IAA farmers can generate a higher income from non-farm activities (through sale of family labor) than IAA farmers, overall, IAA farmers will have higher income by using their family labor in IAA practices, and not by selling their labor.

Consumption of Fish and Other Protein Food

Farmers were requested to indicate the number of times their household had eaten a given type of protein food (beans, meat, dried fish, fresh fish and chicken) during the past month. Overall, dried fish was the protein most frequently consumed, followed by beans and fresh fish (Fig. 4). IAA farming households consumed fresh fish more frequently than non-IAA households and also, on average, stated a higher frequency for all other animal protein foods. Non-IAA farmers consumed, on average, slightly more beans compared to IAA respondents. There was a significant difference between the two groups in the consumption of fresh fish and chicken (Fig. 4). It can be assumed that the consumption of fresh fish (that is more expensive than dried fish) is higher for fish-growing households that do not have to purchase this food. The higher consumption of chicken can be explained by the higher household income of IAA farmers, which leads to an increase in purchased animal protein on top of increased on-farm production. However, beans were still the major protein source in terms of the overall quantity consumed monthly for both groups. The low price of beans may be the explanation.

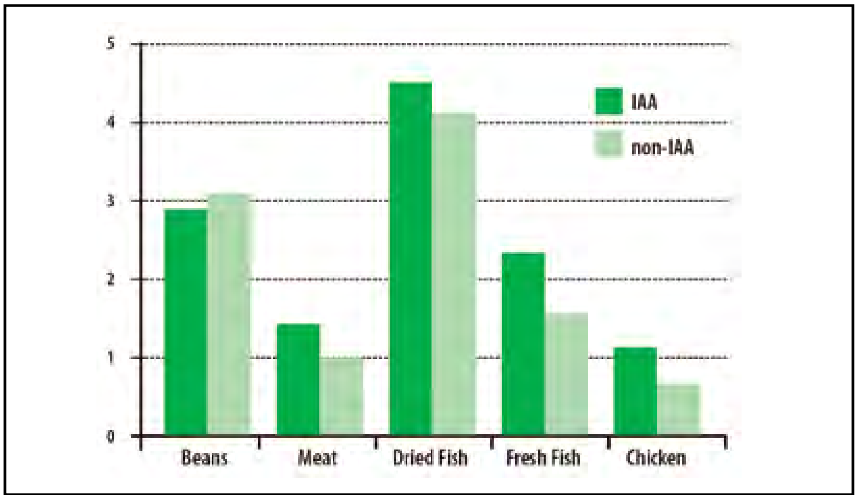

Figure 4. Frequency of protein food consumption within households in the one-month period preceding the interview (based on recall).

Impact on Sustainability

Results from RESTORE analyses indicate that farmers who have integrated their farms with fish farming increased enterprise diversity, increased recycling flows among enterprises, increased the overall biomass production, and increased economic efficiency (Lightfoot et al. 1993). While these may vary over time, the overall observable trend on a given farm adopting IAA is that the values of the sustainability indicators tend to increase with time (Lightfoot and Noble 2001). One underlying hypothesis is that farmers increase their aquaculture knowledge and integrated pond management skills, selecting what fits best in the often variable, agro-ecological and socio-economic context.

In Fig. 5, the case study farm experienced typical variability over the six years shown here. Two years were affected by drought (1991-92, 1994-95) and the farm was stressed by a severe drought during 1993-94. Although enterprises were affected (reflected in reduced production), the farmer managed to achieve high profit cost ratios during the two latter drought years through IAA-enabled strategies such as growing additional varieties of vegetables around ponds using residual moisture from dried-out ponds (Noble 1996).

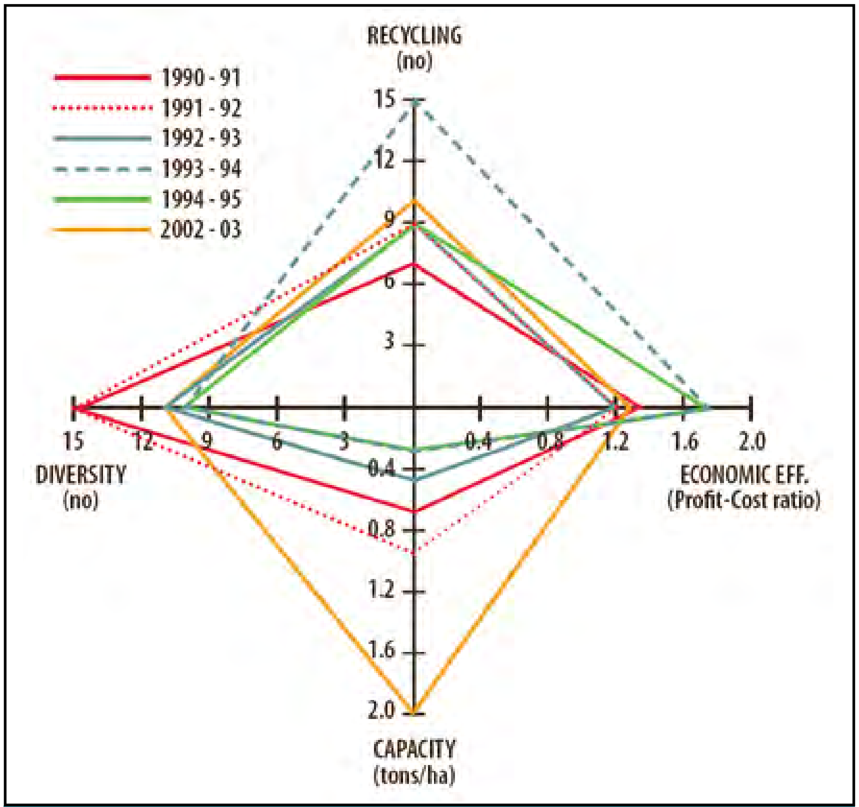

Figure 5. RESTORE 'kite' diagram of four sustainability indicators for the case study farm of Mr. Ishmael Amadu, Malawi.

Fish catch demonstration for visiting farmers from Eastern Province, Zambia.

Welfare Effects and Rate of Return

Project benefits and costs are calculated using a number of assumptions. The cost of IAA technology development by The WorldFish Center was around US$1.5 million for the entire period from 1986 to 1994. Another US$100 000 per year was added to account for the costs incurred by the collaborating national aquatic research systems (NARS). From 1994 onwards, US$100 000 per year was added to reflect the cost of dissemination activities undertaken by the Government of Malawi and various NGOs.

The supply impact of R&D on IAA in Malawi was estimated from the increase in aquaculture production. Twenty-five percent of the growth was attributed to growth in demand, the remainder divided equally between yield increase and area growth. Assuming that two thirds of the observed growth in aquaculture was attributable to the WorldFish project, a net present value of some US$800 000, a benefit cost ratio of 1.4, and an internal rate of return of 15 per cent was calculated. Most of the benefits (60 per cent) go to consumers through lower fish prices.

Conclusion

This study is an example of a comprehensive impact assessment framework using a combination of methodological tools to assess the impact of a complex natural resource management R&D project. For the analysis, technology adoption and the impacts on the farm household as well as economy-wide welfare effects of the project were attributed to two separate outputs: (i) an integrated multi-output multi-input technology; and (ii) a technology transfer model.

Though the study shows some of the impacts of this type of project, additional data are required to clearly prove the impact this project had in the fields of human health and the environment.

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