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Ex-ante assessment of integrated aquaculture-agriculture adoption and impact in Southern Malawi

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Abstract

There are increasing requirements for impact assessment by development partners in order to increase the accountability and effectiveness of research and development projects. Impact assessment research has been dominated by conventional economic methods. This context challenges agricultural research organizations to develop and apply alternative impact assessment methods incorporating economic, social, and environmental impact components. In this study, we use the Tradeoff Analysis for Multi-Dimensional Impact Assessment (TOA-MD) model to evaluate the impact of integrated aquaculture-agriculture (IAA) adoption in Malawi. The study demonstrated that with a minimal data set, the TOA-MD model can be applied to predict and assess the adoption rates of new technologies and practices as well as their economic and non-economic impacts.

1. Introduction

With the establishment of the Millennium Development Goals (MDGs) and the promotion of the concepts of "evidence-based policy" and "results-based management," there is a growing demand for and stronger emphasis on impact assessment in order to respond to development partners' requirements and increase the accountability and effectiveness of research and development projects (Maredia 2009). Substantial progress has been made in impact assessment research, ranging from technology adoption and diffusion to benefit and welfare distribution to other research areas, using various assessment methods and approaches (de Janvry, Dustan, and Sadoulet 2010; Manyong et al. 2006; Maredia 2009). The practice of impact assessment in international agricultural research and development has traditionally been dominated by experimental and statistical/econometric approaches that focus on economic measures. Due to limitations in method development, impact assessments of natural resource management, social science and policy, biodiversity, and ecosystem services have been facing great challenges (Kelley, Ryan, and Gregersen 2008; Renkow and Byerlee 2010). There is increasing demand to move beyond conventional economic methods to methods of impact assessment covering economic, social, and environmental components—multi-dimensional impact assessment. However, there are still relatively few such assessments of agricultural research and technologies (Antle 2011; Claessens, Stoorvogel, and Antle 2009; Walker et al. 2008). Typically, impact assessment research has to be done under tight budgetary constraints, during rapid institutional transformation, and in a limited time. This context challenges agricultural research organizations to develop and apply new or alternative impact assessment methods for generating vital knowledge on past, present, and likely future impacts of research portfolios for policy making as well as research design and prioritization (Antle 2011).

In this study, we use the Tradeoff Analysis for Multi-Dimensional Impact Assessment (TOA-MD) model to evaluate the impact of integrated aquaculture-agriculture (IAA) adoption in Malawi. The TOA-MD model is a multi-dimensional impact assessment model recently developed by Antle and Valdivia (2011). The model uses a statistical description of a farm population to simulate adoption and impacts of a new set of technologies or practices. This approach moves the focus of impact assessment modeling from site-specific, process-based models and data to the use of statistical simulation models parameterized with population data (Antle 2011; Antle and Valdivia 2006). We will demonstrate that with a minimal data set drawn from a farm household survey of the type frequently utilized in agriculture development research and other available secondary data sources, the TOA-MD model can be applied to predict and assess the adoption rates of new technologies and practices as well as their economic and non-economic impacts.

Malawi has considerable aquatic resources in its lakes and rivers, and the capture fisheries sector contributes 4 percent of GDP (Nagoli et al. 2009). However, capture fisheries production has declined dramatically during the last 30 years, with fish consumption dropping from 14 kg/capita to about 4 kg/capita (FAO 2009). Despite this decline, fish account for 70 percent of animal protein, on average, in diets of rural households (GOM 2002). Meat is the main protein source, with fish supplying only 13 percent of total protein but 80 percent of vitamin B12 (Ecker and Qaim 2010). As a response to the importance of fish for vitamin and animal protein intake, aquaculture is prioritized by the national government and has received considerable attention in recent decades (Nagoli et al. 2009). Due to sustained efforts by national and international development organizations, household aquaculture in Malawi has developed steadily. Given dietary preferences for fish, the growth of aquaculture has improved nutrition for rural farming households, as well as providing an additional source of income. Aquaculture in Malawi is mostly a farm enterprise, with the typical farm having two or three small ponds. There are few cases of small or medium enterprise-type production (Russell et al. 2008). Using geographical information system (GIS) analysis combined with biophysical and socioeconomic assessments, Kam et al. (2008) and Kam and Teoh (2008) suggested that about 35.4 km2 of land area in Southern Malawi is suitable for aquaculture development.

As illustrated in Figure 1, the Chingale Extension Planning Area, part of Zomba and Machinga Districts, is located in the Southern Region of Malawi and is one of the areas where aquaculture and integrated aquaculture-agriculture (IAA) systems have been adopted by farm households. Aquaculture in Chingale dates back to the late 1980s, but adoption rates grew substantially in the early 2000s, when aquaculture practices were transformed from an individual basis toward the formation of aquaculture farming clubs under the support of World Vision International, WorldFish, and Government of Malawi initiatives (Nagoli et al. 2009).

Efforts to promote aquaculture development in Malawi in general and in Chingale in particular include the concept of IAA systems. The IAA strategy was proposed in part due to past failures in promoting aquaculture as a stand-alone enterprise. The stand-alone strategy requires large investments in skilled labor and financial capital, which are not available in poor rural farming communities. IAA is based on the concept of recycling inputs and nutrients among different components of the farm. This approach encourages crop diversification and efficient use of different on-farm resources and consequently is hypothesized to increase farm household income and food security, as well as nutritional status.

To date, several impact assessments of IAA systems in Malawi have been carried out (Dey et al. 2006, 2010; FAO 2008; Russell et al. 2008). These previous assessments focused on analyzing determinants of adoption, evaluating aggregate economic impacts, and estimating a rate of return on investment using economic assessment approaches (Antle and Valdivia 2011). Previous studies also used qualitative and descriptive statistics approaches to assess non-economic impacts such as nutrition by examining impacts on a stratified random sample of farms with and without aquaculture production. These studies failed to provide an estimate of overall adoption rate, economic impacts, and non-economic impacts of IAA adoption in the target population of farms; that is, those farms that have the potential to adopt the IAA technology (Antle and Valdivia 2011). Furthermore, since these impact assessments were carried out within a few years of project termination, the findings are representative only for short-term project impacts, not long-term impacts on the farm population.

Via this study we will address the following questions:

- What is the rate of IAA adoption in farming communities in Chingale, Southern Malawi?
- What are outcomes of IAA adoption on household poverty and farm household food consumption?

2. Study Methods

TOA-MD modeling approach

We use the TOA-MD model to estimate the adoption and impact of IAA in Chingale. The model was first developed by Antle and Valdivia (2006) and was later adapted in response to the need for a multi-dimensional assessment approach that sufficiently and accurately supports informed decision making but is also sufficiently low cost in terms of required data, time, and human resources, as well as being based on established economic and statistical theory. This model is parsimonious, can use many types of available data (including survey data, experimental data, or parameters elicited from scientists and farmers), and can be used for estimating various kinds of adoption and for ex-post and ex-ante impact assessments (Antle 2011). The TOA-MD model has been used for evaluating payments for ecosystem services (Antle et al. 2010; Antle and Valdivia 2006), impact of technology adoption (Carleton 2012; Claessens et al. 2009), and climate change adaptation (Claessens et al. 2012). The parametric TOA-MD model is developed as follows (Antle 2011): Consider that farms are presented with a binary decision, either continuing to operate with the current production system, System 1, or switching to an alternative system, System 2. Define NR_1 and NR_2 as expected net returns to System 1 and System 2, and $\omega = NR_1 - NR_2$ as the opportunity cost of switching from System 1 to System 2. The opportunity cost ω is assumed to be normally distributed with mean μ_ω and variance σ^2_ω

$$\mu_\omega = \mu_1 + \mu_2 \quad (1)$$

$$\sigma^2_\omega = \sigma^2_1 + \sigma^2_2 - 2\rho_{12}\sigma_1\sigma_2 \quad (2)$$

where μ_1, μ_2, σ^2_1, and σ^2_2 are the mean and variance of net returns to System 1 and System 2, and ρ_{12} is the correlation between returns to System 1 and System 2 (between-systems correlation).

Farmers are further assumed to maximize profit, and this will induce an ordering ω over all farms such that for the adoption threshold a, farmers will operate with System 1 if $\omega < a$ and choose System 2 if $\omega > a$. Antle (2011) shows that farms will select themselves into adopter and non-adopter groups, and the rate of farms switching to System 2 (the adoption rate) is defined by the accumulative distribution function:

$$r(2,a) \int_{-\infty}^{a} \phi(\omega)\, d\omega,\ 0 \leq r(2,a) \leq 1, \quad (3)$$

where $\phi(\omega)$ is the density function, which is a function of prices and other exogenous variables. The rate of farms remaining in System 1 is then

$$r(1,a) \equiv 1 - r(2,a). \quad (4)$$

In addition to the adoption rate, consider outcome variables, which can be economic, environmental, or social indicators associated with technology adoption processes. These outcome variables and the opportunity cost ω are jointly distributed, because they are normally influenced by many of the same factors (Antle 2011). Using Bayes' rule, Antle (2011) shows that the joint distribution between the opportunity cost ω and an arbitrary outcome k can be written as:

$$\phi(\omega,k|h,a) \equiv \phi(\omega,k|h)/r(h,a) = \phi(\omega,k|h)\ \varphi(\omega)/r(h,a), \quad (5)$$

where h =1,2 represents the farming system and other variables are defined as above. This joint distribution is truncated by a threshold a from below for System 1 and from above for System 2. The joint distribution described in equation (5) depends on the mean and variance of, and correlations between, the opportunity cost ω, outcome variable k, and farming system h joined in the model. According to Antle (2011), three types of correlations are presented in the model: ρ_k represents *between-system* correlations of a given outcome k; $\kappa_k(h)$ represents *within-system* correlations between economic returns *NR* and another outcome; and $\theta_k(h)$ stands for the correlation between an outcome of a system and opportunity cost. Equation (5) links the adoption process to the conditional outcome distributions and plays a critical role in the impact assessment of the model.

Antle (2011) shows that the means and variances of outcome variable k for the truncated portions of farms using System h with adoption threshold a are:

$$\mu_k(h,a) = \mu_k(h) - (-1)^h\, \sigma_k(h)\, \theta_k(h)\, \lambda(a,h), \quad (6)$$

$$\sigma^2_k(h,a) = \sigma^2_k(h)\ \{(1 - \theta_k(h)^2) + \theta_k(h)^2\ (1 + (-1)^{h-1}\, a\lambda(a,h) - \lambda(a,h)^2)\}, \quad (7)$$

where $\lambda(a,h)$ is the inverse Mills' ratio associated with the distribution of the truncated opportunity cost of System h. Equations (6) and (7) show that to ignore the adoption/selection process will result in biased estimates of impact in the adopter and non-adopter sub-populations similar to sample selection bias in the sample selection model (Heckman 1979).

TOA-MD software

The TOA-MD 5.0 software (available at the Tradeoffs website at http://tradeoffs.oregonstate.edu) is programmed in SAS and Excel. Both use the same, standardized Excel data file, which includes complete documentation of the model parameters and outputs.

System design, data collection, and TOA-MD analysis

A farm survey was conducted in early 2012 in Chingale, covering Zomba and Machinga Districts and representing various agro-ecological and socioeconomic conditions of the southern part of Malawi. The study population is the set of farming households in Chingale who potentially can adopt IAA in their farming systems; this includes farms that already have ponds (with low or no integration). In other words, those farms without ecological potential for aquaculture are excluded. It is assumed that farming households in the study population have similar natural resource access and environmental conditions for utilizing IAA technologies and practices. As described above, it is also assumed that the farming population under consideration will select themselves into one of two systems: System 1 is defined as those farms that do not practice aquaculture or practice IAA but with a low level of integration. In System 1, there are two strata of non-IAA farms: those that have an aquaculture pond but with a low level of integration and those without an aquaculture pond. System 2 is defined as those farms that practice IAA with a high level of integration (Figure 2). Following Antle and Valdivia (2011) we define IAA farms with high integration as aquaculture farms having more than two bio-resource flows. The inclusion of farms without ponds in System 1 follows the logic that IAA adoption is not linear; farmers can include aquaculture in their production system without IAA practices and then later incorporate IAA. A bio-resource flow is defined as a flow of a biological resource or energy (product or by- product) from one sub-system to another sub-system in the farm. Manure from livestock to crops, rice bran from crops to tilapia, and tree leaves to goats are typical bio-resource flows.

A stratified sampling method was used to select a sample of farmers practicing non-IAA and IAA systems in the Chingale catchment. The catchment was divided geographically into three clusters from north to south. In consultation with local extension officers and key informants, respondents in villages located in the three clusters were proportionally and randomly selected for interviews. Based on farmer recall, the survey recorded information from the 2010/2011 season, and data were collected on (1) socioeconomic farmer profiles; (2) farming environment; (3) sources of income (4) production systems (5) inputs, outputs, and profitability of farming enterprises; (6) food availability and consumption; and (7) constraints to IAA development.

In order to implement the TOA-MD assessment, a survey was co-developed and implemented by the WorldFish Center staff at its headquarters in Penang and in its Malawi office. Training of enumerators was done by the Malawi team on 11 January 2012 in Zomba. Pretesting of the questionnaire was done in eastern Zomba District on 12 January 2012. The actual survey ran from 16 to 24 January 2012. Two teams of 14 persons were formed, and the survey started in the lower and upper catchments, where farmers are just beginning to adopt the IAA technologies. After that, interviews were conducted in the middle catchment, where more households are practicing IAA technologies. Cross checking of the questionnaires was conducted on 25 January 2012. Data entry ran from 30 January to 8 February 2012. Data exploration and analysis was conducted in February and March 2012. Out of 320 sampled farmers, 281 were interviewed. Farmers not available during the time of the interviews were dropped from the sample. The farmers that were dropped were not available for a variety of reasons and in the judgment of the survey team did not introduce a systematic bias to the sample.

3. Development and Impact of IAA Systems in Chingale

Traditionally practiced in East Asia (e.g., China and Vietnam), IAA has been widely appreciated as an effective means for rural farmers to improve economic and production performance of their farming systems and strengthen livelihoods (Brummett and Jamu 2011). An IAA system is defined as "one in which waste material from one enterprise is used to improve the production on another, thus increasing the efficiency of both" (Brummett 2002; Brummett and Noble 1995). An IAA system involves various crops, livestock, and aquaculture enterprises that may help provide income while rehabilitating soil through better on-farm nutrient recycling and retention. One key element of an IAA system is the farmer-managed flows of biological resources among farm enterprises. Especially where non-farm inputs are expensive or scarce, farmers can use on-farm biological resources from one enterprise for another to enhance farm productivity and production, and to reduce farm production costs.

The IAA concept and its application have been a focus of research and development interest in Africa (Brummett and Jamu 2011). Efforts to introduce IAA technologies to small-scale farmers in Malawi were pioneered in the 1980s by the WorldFish Center and various donors and development NGOs, notably BMZ/GTZ, DANIDA, USAID, OXFAM, World Vision, and CARE (Brummett and Jamu 2011; Lightfoot et al. 1993). According to Dey et al. (2007), IAA research conducted by the WorldFish Center in Malawi can be grouped into two periods. During the initial phase from 1986 to 1990, WorldFish and national partners carried out abroad range of interdisciplinary research for adapting and integrating aquaculture into rural farming systems in the country. On-station aquaculture research was carried out at the Malawi National Aquaculture Center, and the technologies developed there were disseminated to farmers through the Malawi German Fisheries and Aquaculture Development Project (MAGFAD). A range of IAA technologies potentially suitable for small-scale production were developed during this period; however, the adoption of these technologies remained low. In response, WorldFish implemented the farmer-scientist research partnership (FSRP) approach for aquaculture technology development and dissemination (Brummett and Noble 1995). Starting in 1991, this enterprise marked the beginning of the second phase of IAA research. The FSRP approach emphasizes on-farm participatory action research, and compared to the earlier efforts, it has resulted in a higher number of farmers being interested in adopting IAA technology. From 34 farms participating in IAA on-farm trials with WorldFish during 1991–1995, more than 7,000 farms in Malawi had adopted IAA systems by 2004 (Brummett and Jamu 2011). Unfortunately, there have not been any studies that have measured or predicted an actual adoption rate of IAA technology (Antle and Valdivia 2011).

The Chingale Extension Planning Unit in Zomba District in Southern Malawi is one of the areas where relatively more aquaculture households have adopted IAA. Current aquaculture pond area and potential land area suitable for aquaculture development in this region are estimated at 16 ha and 8,681 ha, respectively (derived from Kam and Teoh 2008). Utilization of "dambos," a class of complex and shallow wetlands and gardens for crops and fish ponds, is commonly practiced. The presence of rivers and streams in Chingale has also prompted many farmers or households to divert them for irrigation or fish farming or both. Thus, even in an area where aquaculture is extensively practiced, there is still considerable potential for expansion.

Summary statistics from the survey sample are presented in Table 1. Note that a typical aquaculture/pond area per household is about 500 square meters, and aquaculture households typically have one or two ponds. Aquaculture households (including both high and low levels of IAA integration) have larger farm sizes compared to non-aquaculture households. Aquaculture households also keep higher numbers of livestock and poultry than non-aquaculture households (herd size in aggregation). In contrast, non-aquaculture households earn more off-farm income than aquaculture households. As expected, households identified as IAA adopters have higher numbers of bio-resource flows circulating among agriculture and aquaculture enterprises on the farm.

Impact indicators

This study hypothesizes that compared to non-adopters, adoption of IAA will improve farm incomes and increase food consumption. The TOA-MD model can be flexibly set up to calculate a variety of indicators. Here it is used to calculate poverty rates, farm and per capita income, and per capita food consumption of various food basket items.

Mean farm income and per capita income: Dey et al. (2010) report mean farm income in their study covering three regions of Southern Malawi as 420 USD/year, with per capita income at about 160 USD/year. In their sample, aquaculture production contributed about 8 to 10 percent to the annual income of fish farming households. Farmers in the current study commonly practice mixed farming activities, including crops, livestock, and aquaculture. Maize is the staple crop, though other crops such as cassava, beans, and a variety of vegetables are grown. Mean farm income and per capita income from the survey sample are presented in Table 1.

Poverty rate: Poverty rates in Southern Malawi are high. Different sources report rates from 65 percent to 78 percent (IFAD 2006). The Government of Malawi establishes the official poverty line as 16,165 Mk/year. Using the exchange rate at the time of the study, this translates to 0.27 USD/day (1 USD was 164.5 Mk in January 2012, when the survey was carried out).

Food consumption: Food and nutrition insecurity is chronic throughout Malawi. Ecker and Qaim (2010) estimate that 35 percent of all households are calorie deficient, with varying levels of micronutrient deficiencies; for example, 84 percent of households are vitamin B12 deficient. Food security has increased in recent years, but many households still experience lean periods during the year, which translates to nutrition insecurity. In this study, we used food consumption, including consumption per month of beans, meat, and dried and fresh fish, as a proxy for food and nutrition security. Respondents were asked how often their household consumes these food items per week and the amount consumed per month. Per capita consumption was then calculated by dividing the amounts by number of persons living in the household. This assumes that food consumption is evenly distributed in the household, which various authors have questioned (Ecker and Qaim 2010). Descriptive statistics of food consumption collected from the survey sample are reported in Table 1. Aquaculture households (including low and high level of IAA integration) consumed more meat and fish than non-aquaculture households.

4. Results and Discussion

The results of the analysis are presented in the figures and summarized below.

Figure 3 presents the simulated adoption rate of IAA systems for the whole population of farms. Recall from the discussion above that adoption is a decision to switch from System 1 to System 2 based on expected returns. The model assumes that farmers are economically rational and seek to maximize expected returns. For the population surveyed in the present study, the adoption rate was 58 percent (where the curve crosses the horizontal axis in Figure 3). The vertical axis represents the opportunity cost of adopting. The model constructs this as the cost of remaining in System 1; thus when the opportunity cost is negative, farmers switch to System 2.

The adoption rates for the two sub-populations (i.e., farms with ponds and low integration and farms with no ponds) are presented in Figure 4. The predicted adoption rate of IAA among farms previously without an aquaculture pond is 65 percent, while that of IAA farms with a low level of integration is 48 percent. The adoption rate estimated for IAA farms with low integration is similar to the adoption rate of 49 percent estimated for Zomba District by Antle and Valdivia (2011). Compared to farms without ponds, the sub-population of IAA farms with low integration is less likely to realize expected returns in System 2 greater than they already earn in System 1. While this result may appear contrary to expectations, it must be recognized that IAA is a knowledge-intensive practice. Adoption means learning new resource flow management practices, and farmers who already have an aquaculture pond may feel that the investment of time (the opportunity cost) needed to learn new practices is not worth the relatively smaller increase in return. For the stratum of farmers without a pond, the packaging of technologies may be mutually supporting: Learning fish culture at the same time as learning management of resource flows to support fish culture may create perceived benefits greater than those perceived by farmers who already have a pond and are contemplating the learning cycle of new resource management practices.

Recall that the model assumes that farmers consistently choose to maximize expected returns; in reality, however, they may deviate from that practice. The adoption literature highlights many factors that affect adoption decisions (Feder, Just, and Zilberman 1985), and so the predicted rate may be higher or lower than the actual adoption rate. For example, risk aversion, lack of loans to pay for pond construction costs, labor shortages, or other factors such as a lack of extension services or input markets may constrain adoption. At the same time, there may be incentives to adoption such as the typical activities of a development project: subsidies for pond construction, frequent training visits from extension agents, community support activities, or marketing support. Examining the curves in Figure 3 illustrates the value of such costs. If 100 percent of pond construction costs (estimated at 34,500 Mk for constructing a pond of 500 m2) were subsidized to farms without ponds for switching to an IAA system, the adoption rate would increase from 58 percent to 62 percent for the whole population, and from 65 percent to 71 percent for the stratum of farms without aquaculture.

The model also shows that IAA adoption would increase farm incomes. As presented in Table 2, average farm income would grow 46 percent from the baseline at zero adoption. Among the adopting population the increase is more dramatic, reaching 58 percent. Similar to farm incomes, average per capita incomes grow by 28 percent.

Reducing the poverty rate is the frequently stated goal of development projects. Illustrated in Figure 5, the baseline poverty rates are 46 percent at zero adoption, and that figure drops by 24 percent at the predicted adoption rate. At the predicted population adoption of 62 percent, the poverty rate among adopters is 31 percent, while that of non-adopters is 38 percent. By forcing the model away from the optimal adoption rate, farmers are "forced" to adopt or not adopt, reducing the aggregated expected returns, and thus the poverty rate rises.

Figure 6 illustrates the poverty rate analysis for the farms with and without aquaculture ponds. The farms without ponds have a 51 percent baseline poverty rate, while those with ponds are much lower, at 41 percent. The rates for both strata decline, but the sub-population without ponds enjoys a greater percentage reduction.

In addition to economic outcomes, development policy in Malawi seeks to improve food security. Using simple measures of food consumption per month as an indicator of food security, Table 3 and the remaining figures present simulated impacts of IAA adoption on household per capita consumption of four food items: beans, meat, dried fish, and fresh fish. The results show per capita consumption of meat and fresh fish for the farming population in Southern Malawi would increase 15 percent and 29 percent, respectively, compared to the baseline consumption level (Table 3). At the predicted adoption rate, bean consumption of the whole population would only slightly increase (1 percent compared to the baseline level with no IAA adoption), and the dried fish consumption level is predicted to decrease 2 percent compared to the baseline level (Table 3).

Examining the adoption by stratum shows differing results. Reflecting their high baseline household income, the sub-population of farms with fish ponds ate more fresh fish and meat at the baseline, while those without ponds ate more beans and dried fish, which are lower-cost food items. As indicated in the figures and Table 3, farms with fish ponds would increase bean and dried fish consumption and decrease meat and fish consumption when adopting IAA technology. Incentives for this stratum seem to include the potential for higher income and more beans and vegetables offered by IAA systems. Bean and dried fish consumption of IAA adopters in this stratum would increase 28 percent and 6 percent, respectively, compared to the baseline levels (Table 3). In contrast, non-aquaculture farms would have incentive to adopt IAA systems to increase income, so they would increase meat and fresh fish consumption but stay at almost the same baseline level of bean and dried fish consumption.

As findings of this study and previous studies (Dey et al. 2006) show, IAA adoption can contribute to increased farm income, reduced poverty, and increased food consumption for poor rural farming communities in Southern Malawi. Similar to Dey et al. (2007, 2010) and Antle and Valdivia (2011), we also found that the combination of higher income and food availability resulting from IAA adoption leads to increases in fish and meat consumption, which are both important sources of protein in the diet. For the stratum of the population already owning farm fish ponds, adopting IAA resulted in no increase in meat and fresh fish consumption, because they already consume higher amounts of these items compared to the population as a whole (Table 2). IAA adoption in those households is probably driven more by income goals than food security needs.

5. Conclusions and Recommendations

The study shows that using the TOA-MD model, it is possible to conduct ex-ante impact assessments of technology adoption for a relatively low cost and in a short time frame. Data can be drawn from standard farm household surveys of the type frequently used in development research. Using transparently derived economic decision criteria, the model predicts adoption rates. An inability to credibly estimate adoption is a chronic weakness of impact evaluation, yet it is an important decision criterion for investments in large-scale diffusion projects. The generic characteristics of the model mean that it can be flexibly used to examine the potential adoption and impacts of a wide range of investments

TOA-MD simulated analyses show that IAA technology adoption would have positive impacts on poverty, household income, and food consumption in rural farming communities in Chingale in Southern Malawi. The IAA adoption rate is predicted at 59 percent for the overall population, but that rate varies between farms with aquaculture ponds but not practicing IAA and farms initially without a fish pond. The poverty rate would drop by 22 percent for the whole farming population and 29 percent for IAA adopters. For the overall population, meat and fresh fish consumption are predicted to increase 14 percent and 29 percent, respectively, compared to the current baseline consumption level of these items. This overall figure masks different responses for the strata; IAA adoption by farms initially without fish ponds is predicted to bring increases in meat and fresh fish consumption, while adoption by farms that initially had fish ponds would not lead to consumption changes. Depending on the data and questions desired, the model can facilitate inquiry into different investment options. For example, cost of pond construction is commonly perceived to be a major barrier to adoption. The model shows that 100 percent subsidization of pond construction would increase adoption by only 4 percent. The large majority of adopters would find adopting IAA sufficiently profitable to pay their own pond construction costs. The implication is that funds for pond construction may more profitably be deployed elsewhere.

Adoption decisions taken by farmers are not based only on economic performance but may also depend on many other social and environmental factors. Furthermore, the study was conducted in a relatively short time period, comprising the survey design, survey implementation, data analysis, and modeling and reporting. Complementary approaches are needed to provide richer understanding of farm decision-making processes.

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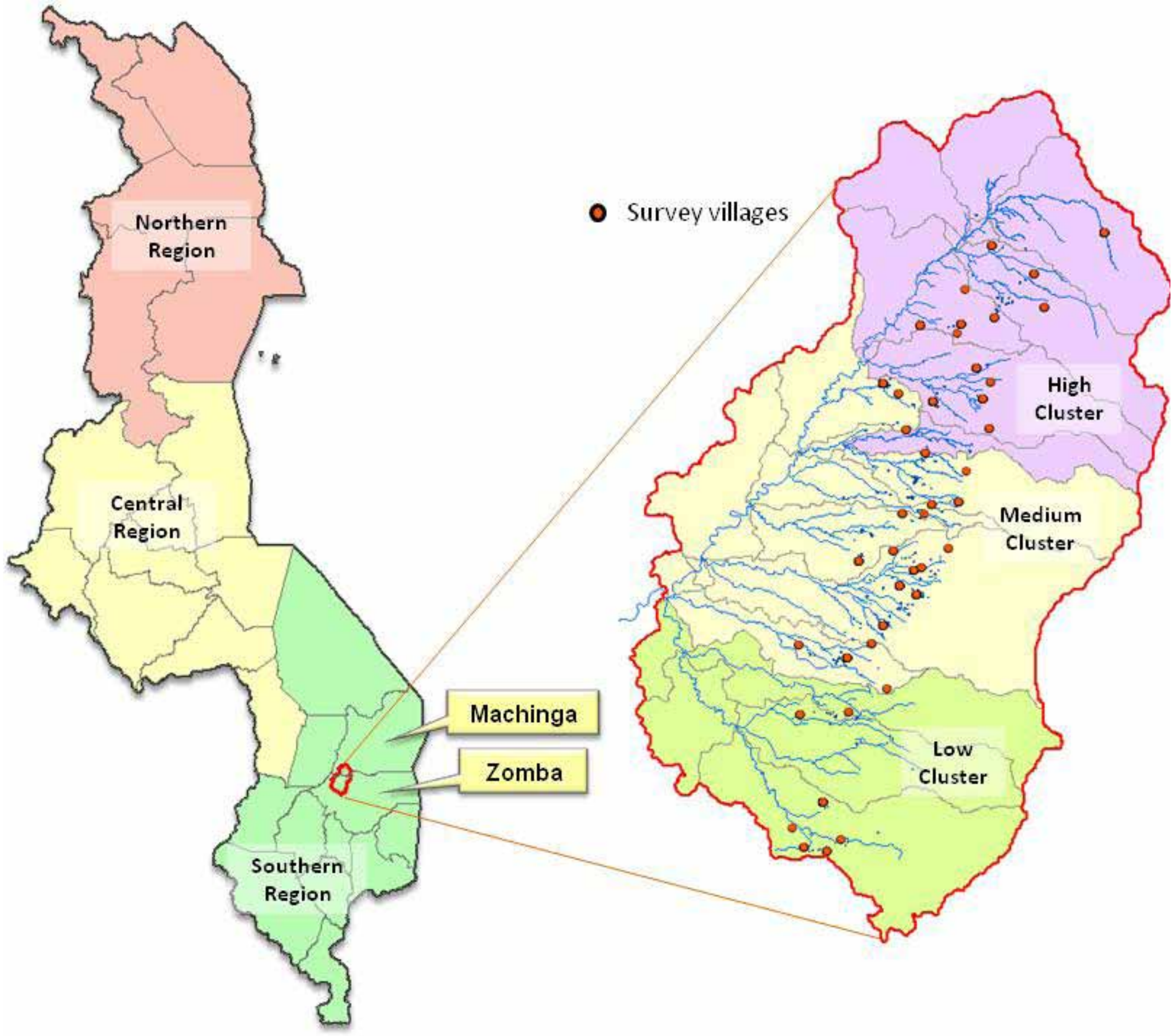

Figure 1. Study site, Chingale Extension Planning Area in the Southern Region of Malawi.

SYSTEM 1	SYSTEM 2	
Stratum 1: Normal aquaculture farms		
	Switching to IAA farms	
Stratum 2: Non-aquaculture farms		

Figure 2. TOA-MD model set-up.

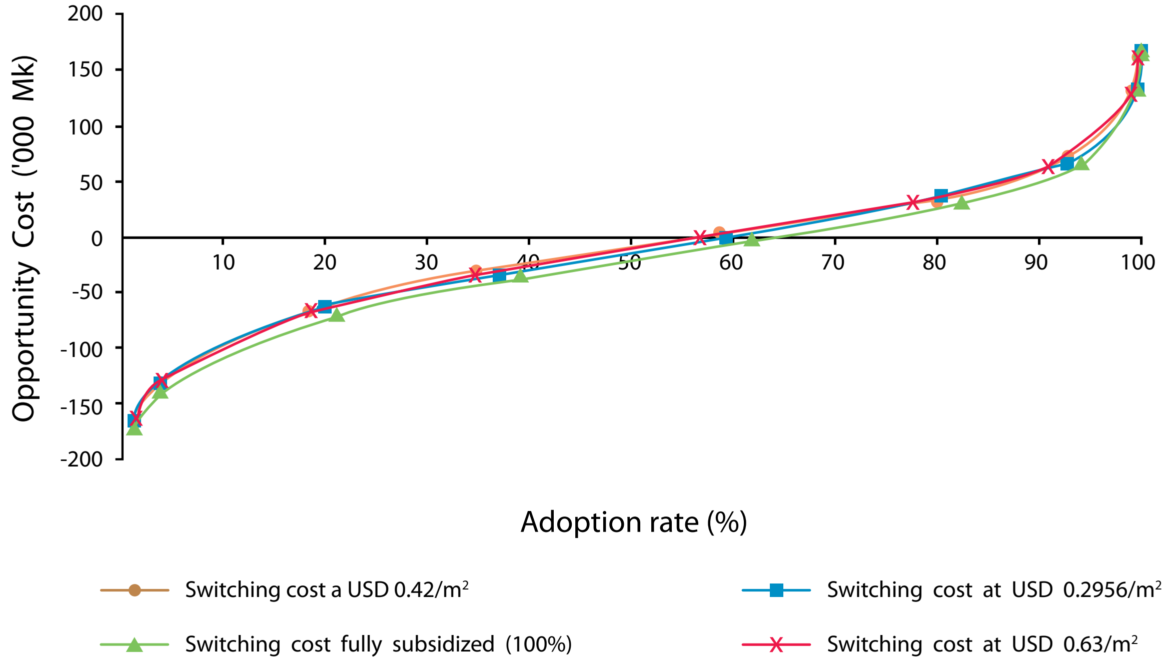

Figure 3. Adoption rate of IAA systems in Chingale, Southern Malawi—predicted rate is point where the curve crosses the horizontal axis

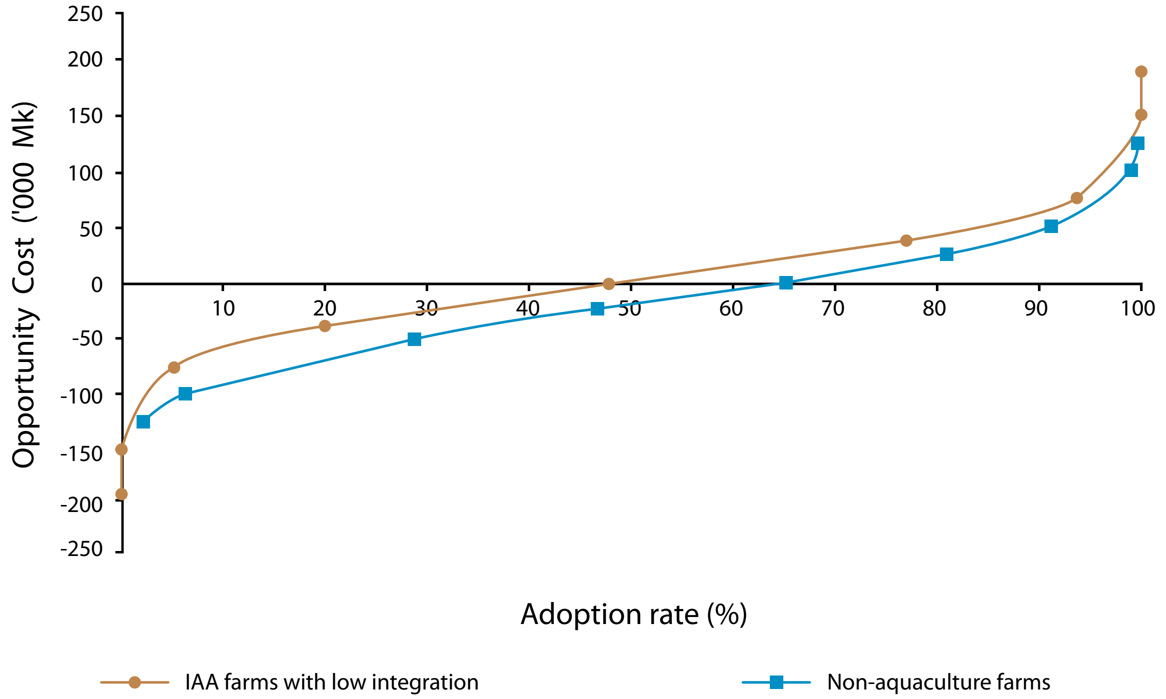

Figure 4. Adoption rate and opportunity cost of IAA adoption in Chingale by stratum.

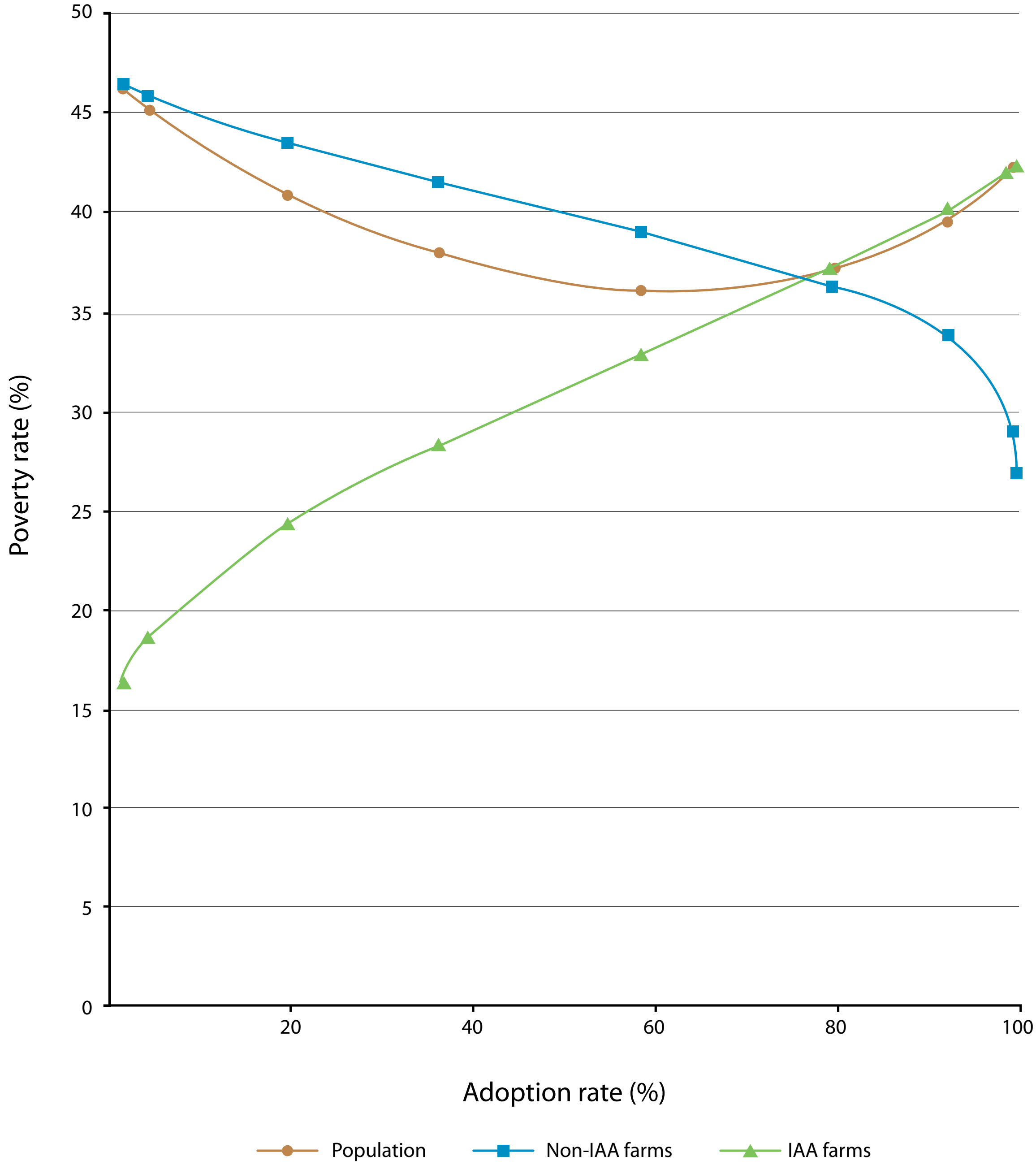

Figure 5. Impact of IAA adoption on the poverty rate.

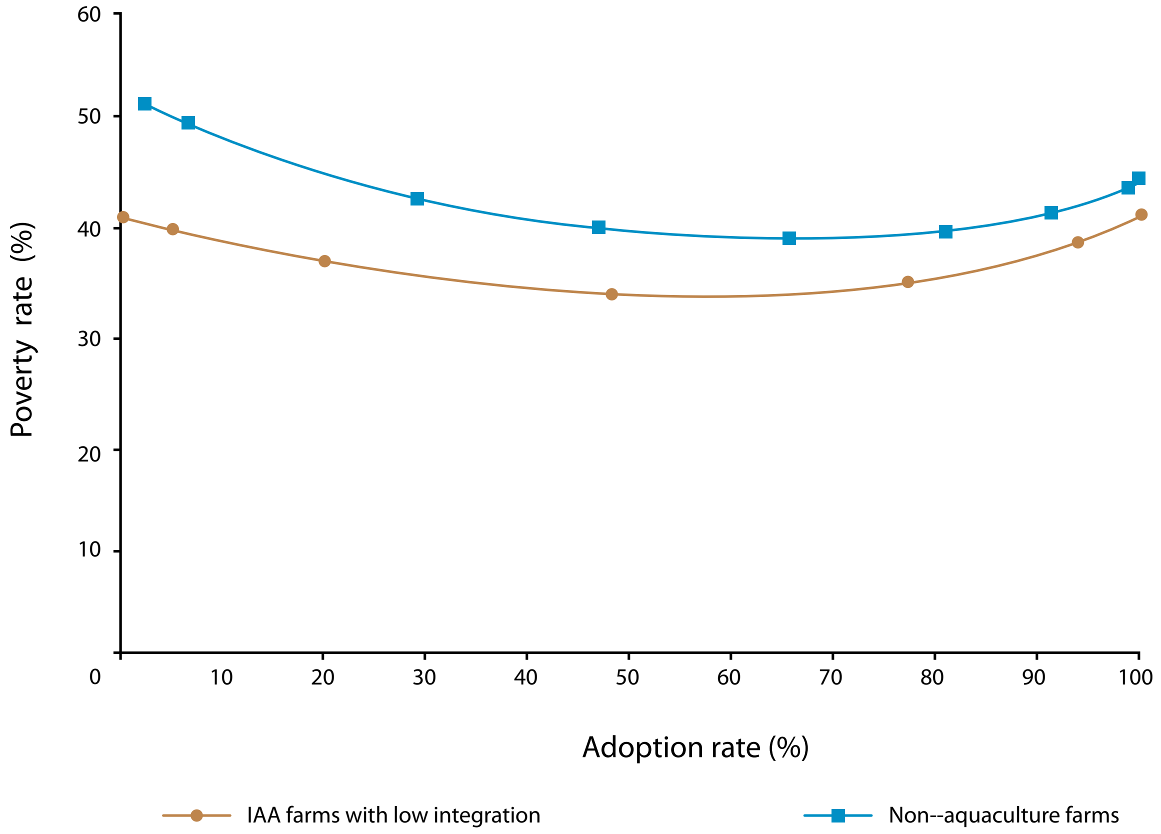

Figure 6. Impact of IAA adoption on the poverty rate by stratum.

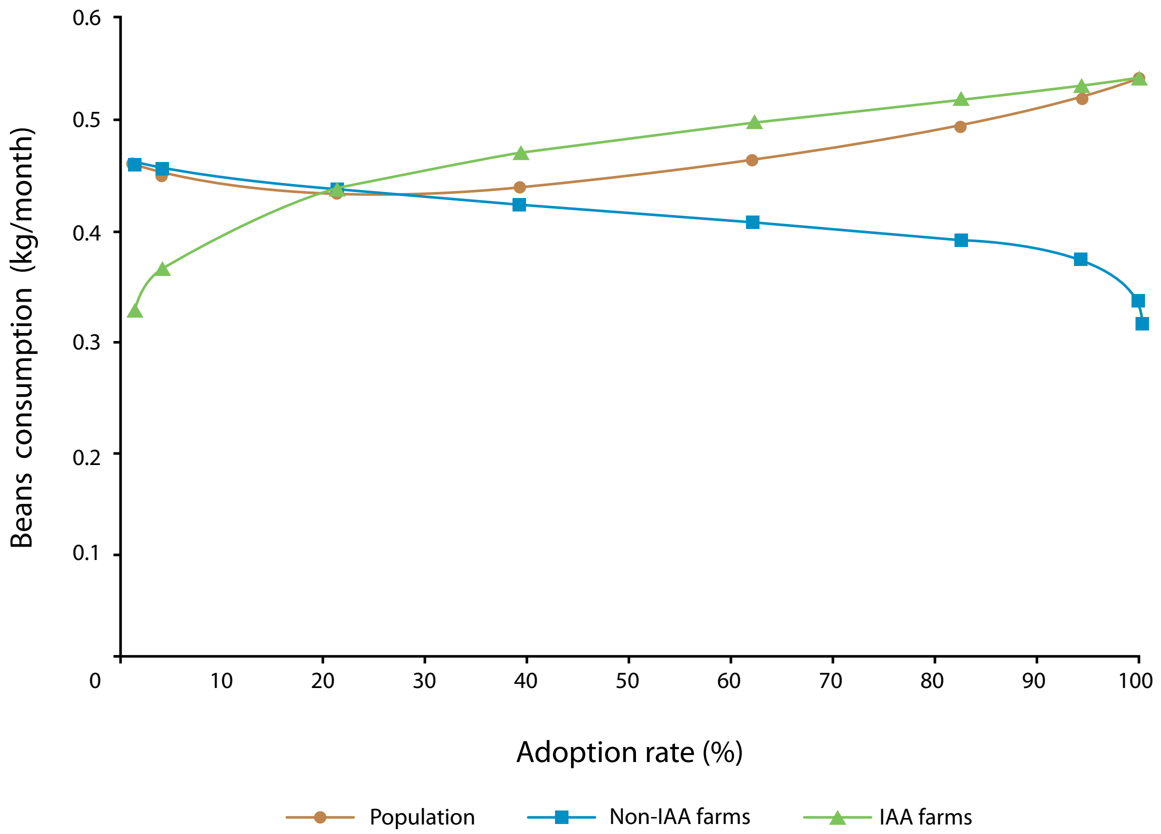

Figure 7. Impact of IAA adoption on household bean consumption (kg/month).

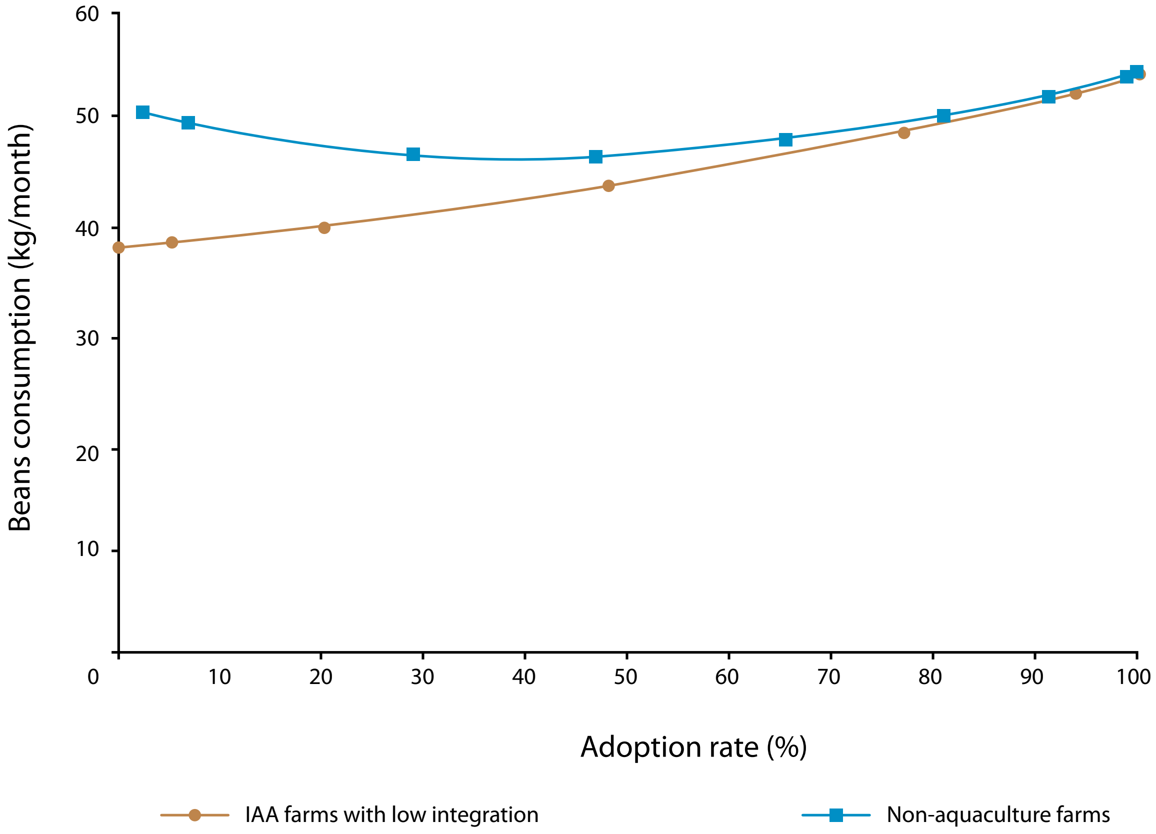

Figure 8. Impact of IAA adoption on household bean consumption by stratum (kg/month).

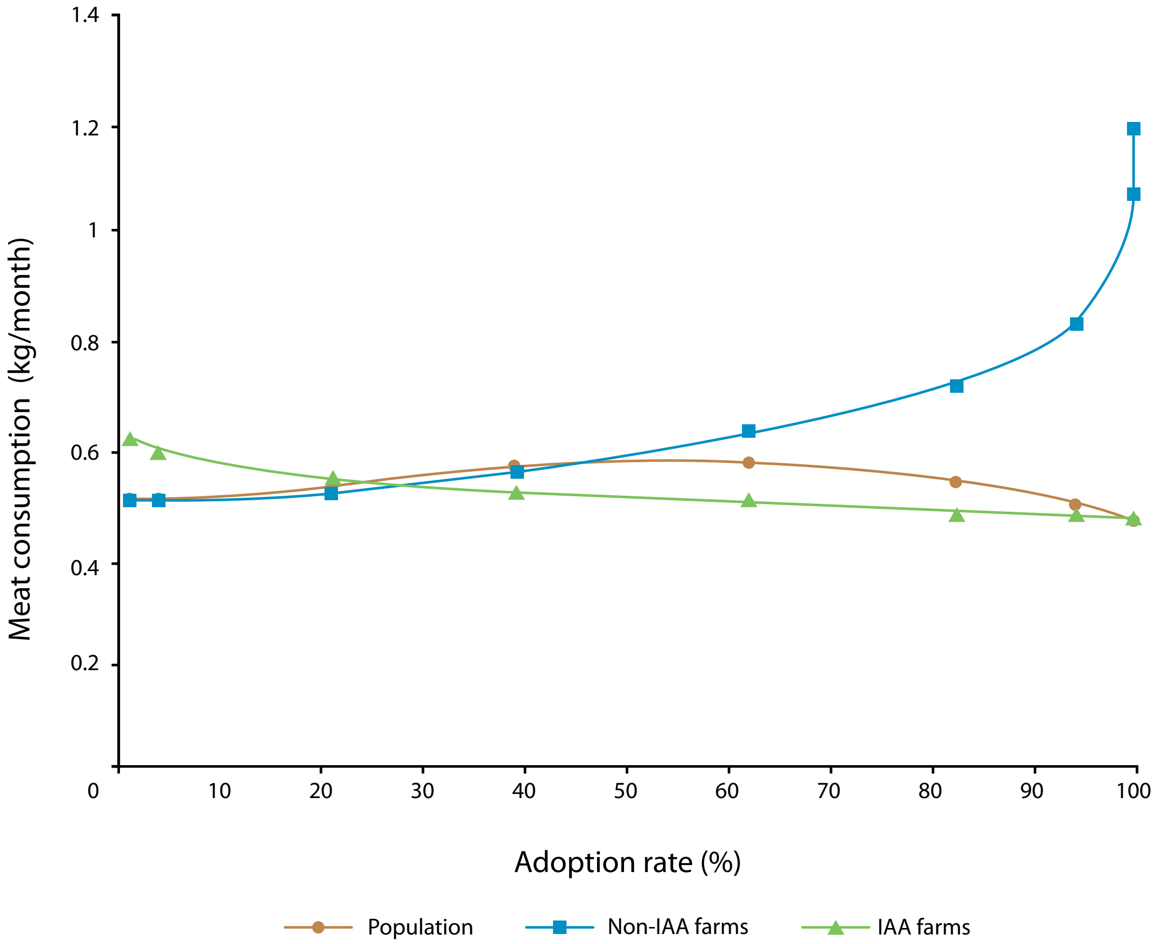

Figure 9. Impact of IAA adoption on household meat consumption (kg/month).

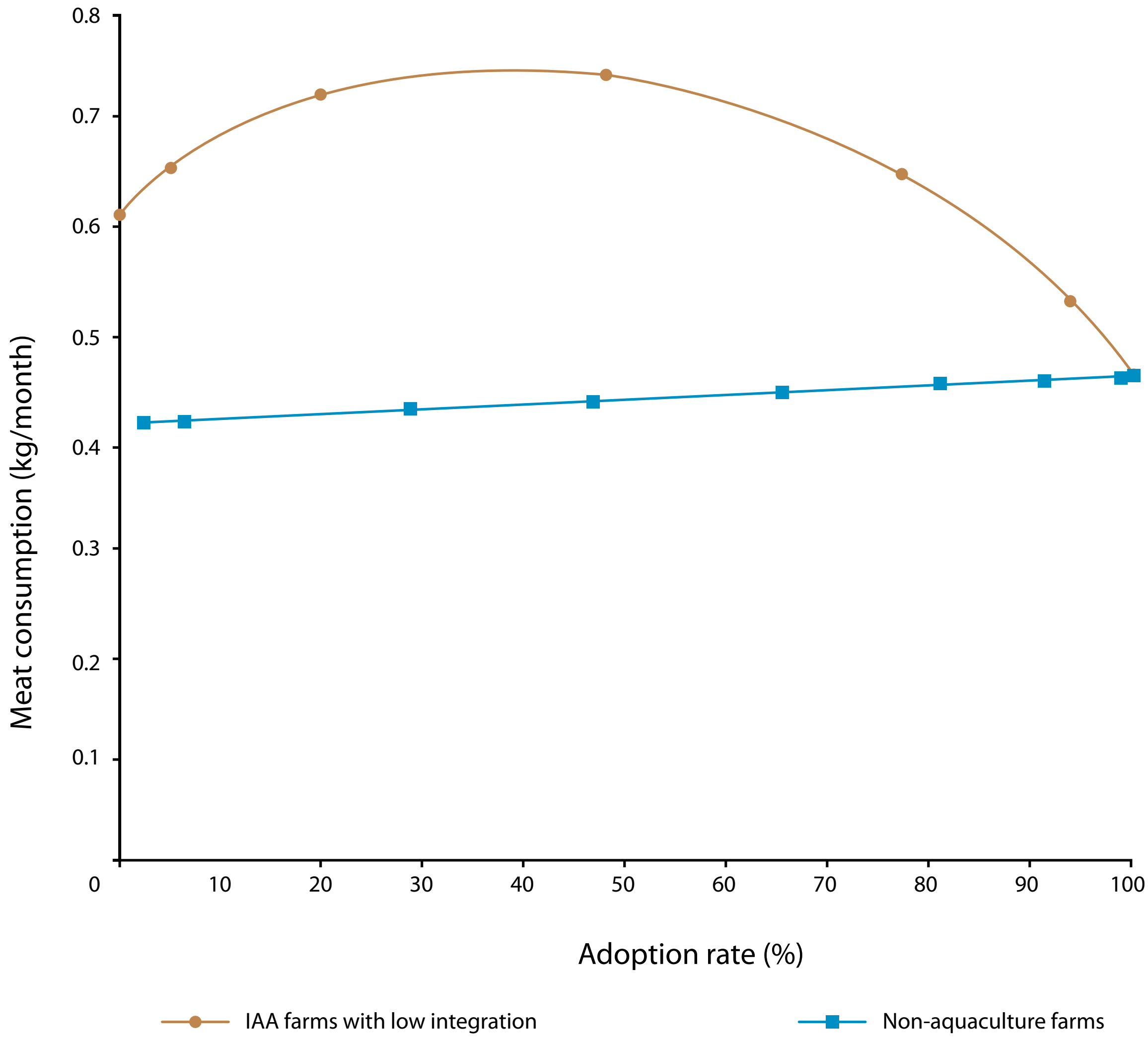

Figure 10. Impact of IAA adoption on household dried fish consumption by stratum (kg/month).

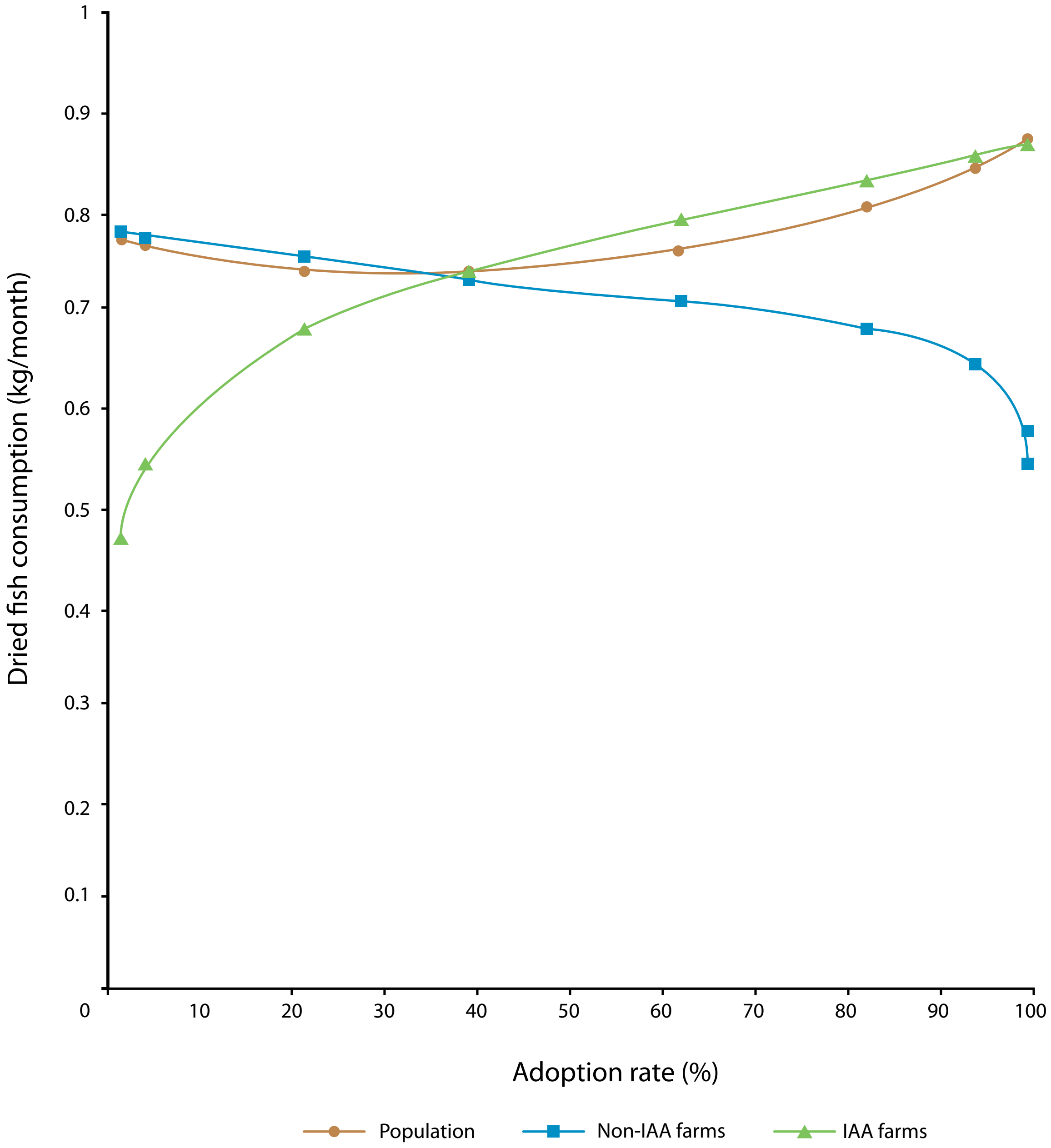

Figure11. Impact of IAA adoption on dried fish consumption (kg/month).

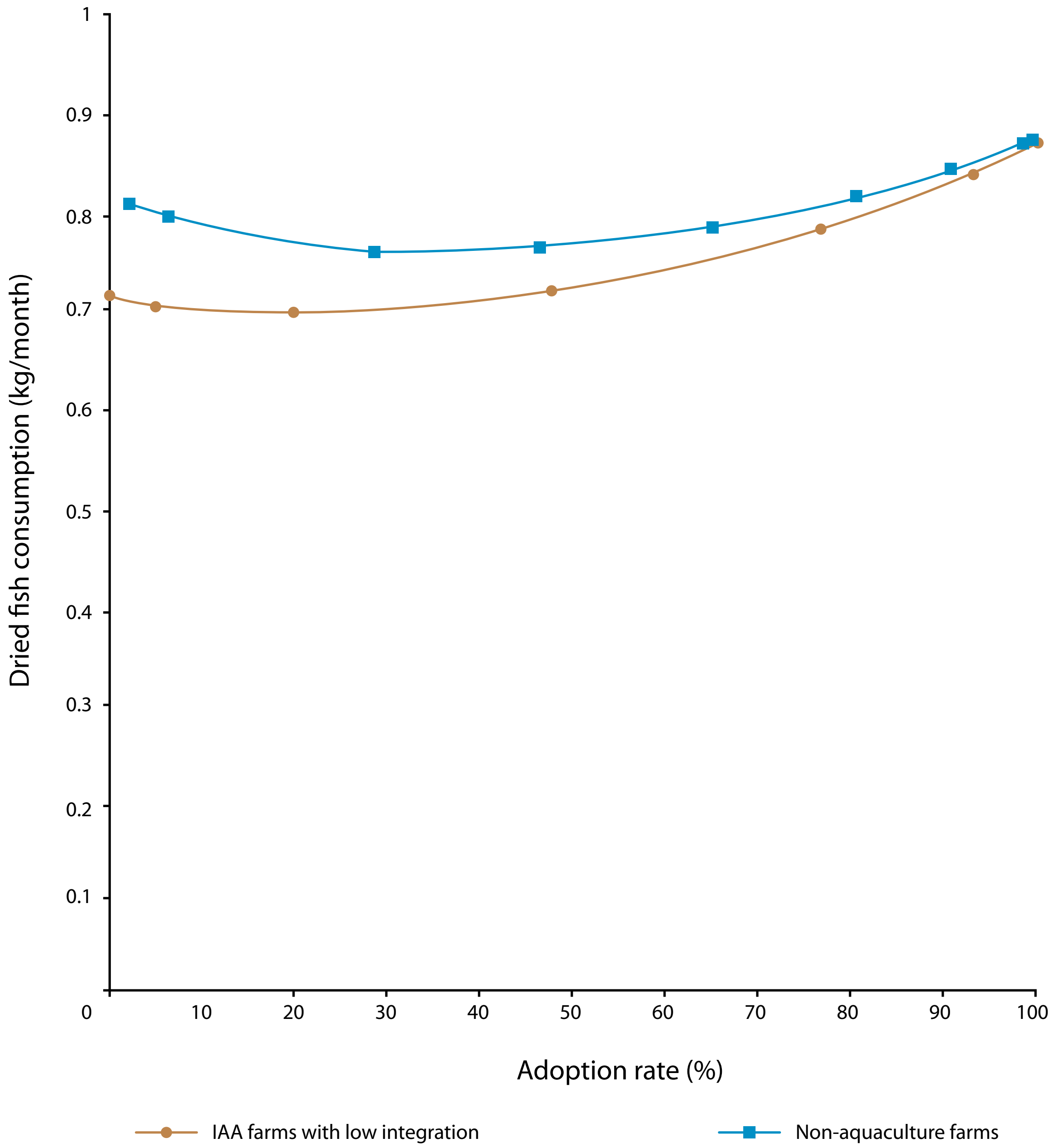

Figure 12. Impact of IAA adoption on household dried fish consumption by stratum (kg/month).

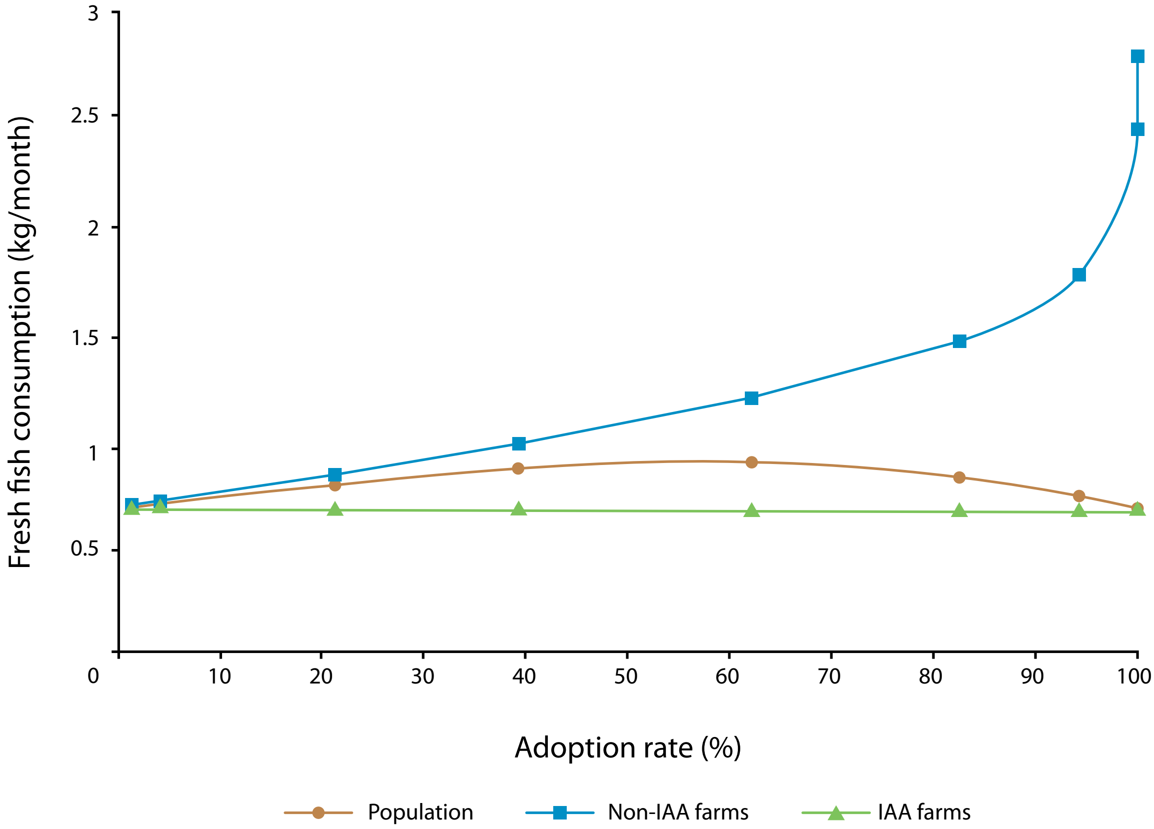

Figure 13. Impact of IAA adoption on household fresh fish consumption (kg/month).

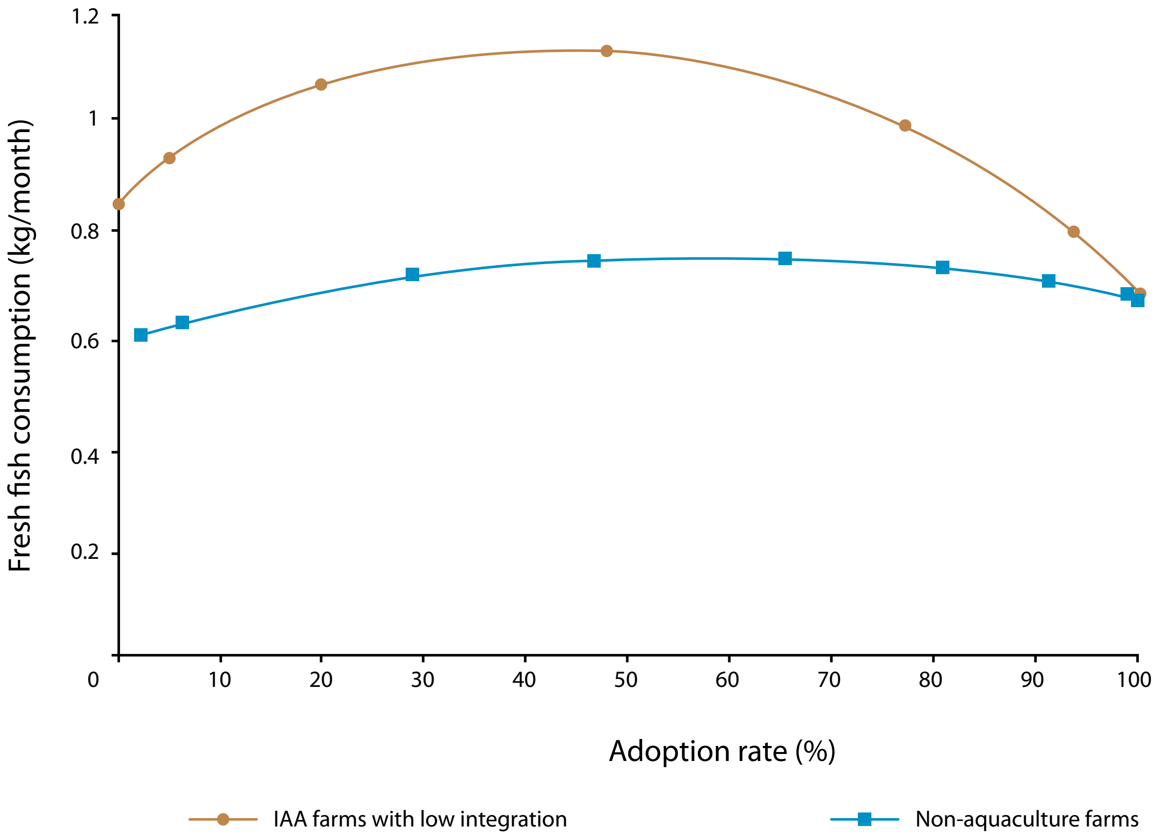

Figure 14. Impact of IAA adoption on household fresh fish consumption by stratum (kg/month).

Table 1. Summary statistics from the sample.

Indicators	System 1		System 2	All
	Non-aquaculture farms	IAA with low integration	IAA farms	
N	145	34	102	281
Household size (number of individuals)	5	5	5	5
Off-farm household income (Mk/year)	31,323	25,352	30,254	30,318
Farm size (ha)	1.20	1.72	1.49	1.37
Aquaculture area (pond size) (ha)	0.03	0.04	0.05	0.05
Herd size (number of head)	3.85	5.35	4.80	4.42
Years of IA/IAA practices	4	4	7	6
No. of bio-resource flows	2	3	5	4
Per farm crop output (Kg)	1,460	1,990	2,129	1,767
Crop productivity (Kg/ha)	1,796	1,645	1,976	1,843
Crop net return (Mk/farm)	39,213	55,817	59,512	48,590
Per farm aquaculture production (Kg)	-	66	69	68
Aquaculture productivity (Kg)	-	2,134	2,017	2,056
Per farm aquaculture net return (Mk)	-	12,633	14,095	13,718
Per capita bean consumption (Kg/week)	0.5	0.4	0.5	0.5
Per capita meat consumption (Kg/month)	0.4	0.6	0.5	0.5
Per capita dried fish consumption (Kg/month)	0.8	0.7	0.9	0.8
Per capita fresh fish consumption (Kg/month)	0.6	0.8	0.7	0.7
Farm income (Mk/year)	66734	89212	91309	78374
Per capita farm income (Mk/year)	15781	20647	19809	17832
Farm income (USD/year)	406	542	555	476
Per capita income (USD/year/person)	96	126	120	108

Note: 1 USD=164.5 Mk in January 2012, when the survey was carried out.

Table 2. Summary results of the impact of IAA adoption on poverty and income.

		Average farm income (Mk/year)			Poverty rate (%)			Average per capita income (Mk/year)		
Stratum	adoption rate (%)	base (no adoption)	% change on population	% change on adopters	base (no adoption)	% change on population	% change on adopters	base (no adoption)	% change on population	% change on adopters
IAA farms with low integration	48	79,721	23	44	41	-18	-34	19,820	20	38
Non-aqua. farms	65	44,444	69	68	51	-25	-25	15,230	39	39
Chingale	59	56,835	46	58	46	-22	-29	17,692	28	40

Note: 1 USD=164.5 Mk in January 2012, when the survey was carried out.

Table 3. Summary results of the impact of IAA adoption on food items consumption.

		Mean weekly bean consumption (kg/person)			Mean monthly meat consumption (kg/person)			Mean monthly dried fish consumption (kg/person)			Mean monthly fresh fish consumption (kg/person)		
Stratum	adoption rate (%)	base (no adoption)	% change on population	% change on adopters	base (no adoption)	% change on population	% change on adopters	base (no adoption)	% change on population	% change on adopters	base (no adoption)	% change on population	% change on adopters
IAA farms with low integration	48	0.38	15	28	0.61	22	-14	0.71	1	6	0.84	34	-13
Non-aqua. farms	65	0.51	-8	-2	0.42	1	12	0.81	-4	-1	0.60	25	6
Chingale	59	0.46	0	8	0.49	14	-1	0.77	-2	2	0.69	29	-3

Note: 1 USD=164.5 Mk in January 2012, when the survey was carried out.

With communities, changing lives

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