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Economic and social impacts of integrated aquaculture-agriculture technologies in Bangladesh

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Abstract

This study estimated the adoption rate of integrated aquaculture-agriculture (IAA) technologies in Bangladesh and their impact on poverty and fish and food consumption in adopting households. We used a novel, simulation-based approach to impact assessment called Tradeoff Analysis for Multi-Dimensional Impact Assessment (TOA-MD). We used the TOA-MD model to demonstrate how it is possible to use available data to estimate adoption rates in relevant populations, and to quantify impacts on distributional outcomes such as poverty and food security, thus demonstrating ex ante the potential for further investment in technology dissemination. The analysis used baseline and end-of-project survey data from the WorldFish Center-implemented Development of Sustainable Aquaculture Project (DSAP), promoting IAA. This dataset was used to simulate adoption and assess its impacts on poverty and food security in the target population. We found that, if adopted, IAA had a significant positive impact on reducing poverty and improving food security and income.

1. Introduction

Logically, investors in agricultural development projects would like to know the potential of their investments to achieve impact. This paper shows how existing data can be utilized with an innovative modeling approach to predict adoption and impact. This approach is demonstrated through an economic and social impact evaluation of a project that introduced integrated aquaculture-agriculture (IAA) technologies to smallholder farms in Bangladesh. We utilize existing baseline and end-of-project household survey data to simulate an adoption rate and estimate economic and social impacts. This estimation of adoption provides a unique view of ex-ante potential of investments to further disseminate the technology. IAA is an approach to managing resource flows in the farm that utilizes the synergies of crop-fish production to improve productivity and the possibility of sustainable production (DSAP, 2005). Improved, sustainable production in turn should result in improved farm incomes and household food security. IAA is introduced as a response to the trend of intensification of production, as external inputs that make intensification feasible remain either scarce or unaffordable to many producers (Jahan, Beveridge, & Brooks, 2008).

With a population of 143 million on a land mass of 147 thousand square kilometers, Bangladesh is among the most densely populated countries on earth. Over three quarters of the population lives in rural areas where agriculture is the mainstay of the rural economy. Over half of rural dwellers live below the national poverty line, and over 40 million are classified as undernourished (FAO, 2006). Thus food security and poverty reduction are mainstays of government development efforts. To achieve these goals, the government of Bangladesh prioritizes diversified production, employment, and income generation on farms in its Poverty Reduction Strategy Paper (Bangladesh Planning Commission, 2005).

Bangladesh enjoys enormous aquatic resources, and capture fisheries have been extensively utilized for centuries. However, production from those fisheries has reached a plateau, and to fill the demand for fish, producers have turned to aquaculture. Aquaculture has been among the fastest growing food production sectors in Bangladesh for several decades. Mazid (1999) estimates that 73 percent of rural households are engaged in some form of aquaculture production. The combination of the importance of fish in the diet and to national food security, the availability of resources, the widespread practice of aquaculture, and policy attention has resulted in support for research in the sector.

WorldFish has a long history of involvement in the development and adaptation of appropriate aquaculture technologies and management practices for smallholder farms in target countries. A substantial portion of that research has been conducted with partners in Bangladesh. With the objective of generating an appropriate and sustainable low-cost aquaculture technology for smallholder rural farmers, WorldFish started IAA-based aquaculture research in Bangladesh in the 1990s. Beginning initially with technology-focused research, WorldFish implemented a number of dissemination and disaster recovery projects as these technologies matured and were piloted, and a range of scaling-up, capacity-strengthening, and empowerment strategies have promoted locally appropriate variations of IAA in most parts of the country (Jahan, Beveridge, & Brooks, 2008).

This impact evaluation responds to the ongoing need for learning what works in development. Stimulated by the Paris Declaration principle of managing for results, governments and development agencies have increased their demand for outcomes and impact evaluations that support evidence-based policy. Impact evaluation must respond to the need for timely information for policy formulation and for the allocation of investments to scale up innovations (OECD, n.d.).

This policy environment accelerated the already active research area of impact and outcome evaluation methods, most of which are focused on ex-post analyses. The area of micro-level impact studies that focus on particular technologies and utilize primary data for analysis has seen an expansion of its mandate to move along the impact pathway from intermediate outcomes towards higher-level impacts in economic, social, and environmental spheres (Maredia, 2009). These increased demands have resulted in greater sophistication in methods, which in turn require greater investments in primary data collection. The econometric methods developed to estimate adoption and impacts require cross-section and panel data to be useful (de Janvry, Dustan, & Sadolet, 2010). Cost-benefit analysis is among the popular methods used for ex-ante assessment. Cost-benefit analysis calculates an average benefit based on trials or pilot testing and predicts an expected adoption. This approach is based on a fundamental assumption, shared with most other methods, that farmers are all alike.

This paper uses a new approach to impact assessment via simulation models parameterized with population data (Antle, 2011). The approach was developed as a response to the need for timely quantitative analysis that is sufficiently accurate for policy analysis, responding to a need for ex-ante assessments that can utilize information from pilot studies, experimental data, modeling, or other preliminary information. The approach is implemented through the Tradeoff Analysis for Multi-Dimensional Impact Assessment (TOA-MD) model (Antle & Valdivia, 2006, 2011). The TOA-MD model uses a generic structure and can be used to analyze any quantifiable impacts associated with technology adoption. These could include economic, social, or environmental changes, such as farm income, poverty rate, food security, nutrition, gender roles, soil nutrient management, or other factors. In this paper, we use the model to simulate adoption of IAA technologies and estimate the impact on poverty and fish consumption.

Research conducted by WorldFish on the adoption and impacts of IAA systems in Bangladesh and other countries has mainly emphasized identification of the factors influencing adoption, evaluated aggregate economic impacts, and estimated a rate of return on investment using an assumed adoption rate (Dey et al., 2006, 2010; Jahan & Pemsl, 2011; Russell et al., 2008). Based on the experimental design of before-after and with-without, these studies concluded that if farms adopted IAA they would be better off in terms of outcomes such as productivity, income, and food security, but it was not possible to estimate an overall adoption rate or make statements about the overall impacts of IAA in the relevant population of farms that potentially could adopt the IAA technology, which is the critical aspect needed for ex-ante evaluations.

In this study, we show how the TOA-MD approach can utilize data that were collected in the original impact evaluation surveys, along with other publicly available data, to carry out a disaggregated, multi-dimensional impact evaluation. The TOA-MD approach also provides the basis for carrying out sensitivity analysis to parameters that cannot be estimated with the available data, thus providing guidance about the types of data that should be collected in future impact evaluations.

2. Impact evaluation using TOA-MD

TOA-MD is designed to simulate what would be observed if it were possible to conduct a controlled experiment to measure the effects of farms adopting a new production technology (Antle, 2011; Antle et al., 2010; Antle & Valdivia, 2006). In this study, survey data are used to estimate parameters representing systems used by non-adopter and adopter sub-populations, and the model is then used to simulate adoption in the target population and the impacts that are associated with adoption. Here the target population is defined as all farms in Bangladesh where IAA is technically feasible.

The TOA-MD approach provides a generic, transparent data structure and model, so that a new model does not have to be designed for each application. Further, it can be used with various types of data to carry out either ex-ante or ex-post assessments. The model parameters are means, variances, and correlations of outcome variables (as discussed below), so when survey data are available, simple method-of-moments estimation can be used reliably with relatively small samples; complex, large-sample econometric estimators are not used. When survey data are not available, other types of data, such as experimental data, modeled data, or expert judgment can be used to estimate parameters.

Because the methods proposed for this study are novel, it is useful to explain their motivation. The first is the need for an approach to economic and social (multi-dimensional) assessment that is sufficiently accurate to support informed decision making, but also sufficiently low cost in terms of data, time, and human resources to be feasible for the technologies and populations of interest. Various authors have noted the chronic difficulty in planning, funding, and implementing rigorous impact assessment (Walker et al., 2008).

A second motivation for the TOA-MD model approach is that for most impact assessments, it is necessary to estimate the extent of eventual adoption in relevant populations, because it is prohibitively costly to observe it directly or because the technology has not been widely disseminated. A closely related point is that even when actual adoption rates can be observed, adoption is often incomplete, or there may be future dis-adoption, so it is important to be able to evaluate the potential impacts that would be associated with a range of possible future adoption rates. It is not usually feasible to use conventional econometric adoption models to predict adoption, because data (i.e., the exogenous variables of the models) for the entire population of interest are not available. For example, in ex-post impact assessments of aquaculture in Malawi (Dey et al., 2006) and nutrient management research in the Philippines, Walker et al. (2009) noted that there were no available measurements of adoption, and thus they were forced to assume the extent of adoption in the study area and in other regions where adoption was expected to occur. Walker et al. (2008) observe: "Compared to estimates on other variables in an epIA (ex post impact assessment) on agricultural research, those on adoption are usually shrouded in uncertainty. Economic rate of return assessments are predicated on annual estimates of adoption. It is only for very few technologies that annual estimates can be furnished from primary or secondary data without having to resort to projection or backward forecasting. Sensitivity analysis often shows that estimates of the size of net benefits are more sensitive to adoption levels and rates than to those of any other variable (Walker and Crissman, 1996)" (pp. 33–34).

A third reason for a model-based approach is the prevalence of parameter uncertainty in impact assessment. Parameter uncertainty, where the sample parameters may not represent the population parameters, is a critical issue for almost all impact assessment, whether the analysis is described as ex ante or ex post. Parameter uncertainty leads to model estimation risk, and large, complex econometric or household simulation models with many parameters are not well suited to addressing parameter uncertainty. When technologies are unobservable because they are not yet in use, or when analysis is addressing adaptation to future possible environmental conditions, the relatively small number of easily interpreted parameters in the TOA-MD model facilitates translation of available information, such as experimental data or expert opinion, into parameter values that can be subjected to sensitivity analysis. When technologies are observable but available data are limited, the TOA-MD model can be used to assess the value of collecting additional data to reduce parameter uncertainty.

The basic concept underlying TOA-MD is to use statistical simulation to approximate as well as possible, with available data, the effects of introducing a new technology into a heterogeneous population of potential adopters. It is important to emphasize the recognition of heterogeneity among the adopting population. Ecological and economic variation create variable conditions that affect the adoption decisions of farmers. In turn, these decisions are related to the potential outcomes. The model utilizes this heterogeneity and its correlation to outcomes.

The parameters of the simulation model can be estimated in various ways, using survey data, experimental data, or parameters elicited from scientists and farmers. Antle (2011) shows that a parsimonious impact assessment model can be based on the statistical relationships between adoption and the economic, environmental, and social outcomes associated with adoption. When farmers select themselves into adopting and non-adopting groups, the resulting distributions of outcomes are truncated by the threshold separating adopters from non-adopters, in a manner similar to sample selection models in the econometrics literature. The selection effects of adoption depend on the correlations between variables determining adoption (e.g., expected returns) and outcome variables used to measure impact (e.g., household income, soil erosion, or child nutrition).

Following Antle and Valdivia (2011) in the TOA-MD approach, a threshold model of adoption is used, in which farms are presented with the opportunity to continue operating with the current production system, System 1, or switch to an alternative, System 2. Farms are assumed to choose a system to maximize a function $v(h)$ where $h = 1,2$ indexes the production system and all attributes associated with it, including prices. In this study of IAA impact, we define $v(h)$ as expected returns. This objective function induces an ordering $\omega \equiv v(1) - v(2)$ over all farms, such that for the adoption threshold a, $\omega > a$ for those farms using System 1 and $\omega < a$ for those using System 2. The adoption variable ω is spatially distributed across the landscape according to the density $\varphi(\omega)$, which is generally a function of prices and other exogenous variables.

Antle (2011) shows that the characteristics of the farms selecting themselves into the adopting and non-adopting groups give rise to distinct outcome distributions for each group. A key implication is that if this correlation is ignored (implicitly treated as equal to zero), as would be the case in studies that estimate adoption separately from impact, impact estimates could be substantially biased when adoption is less than 100 percent.

TOA-MD Structure. The following definitions are used for parameters of the population of all farms, both adopters and non-adopters, where outcomes are indexed by $k = v,z$ and systems are indexed by $h = 1,2$, and $k(h)$ refers to outcome k for System h:

$\mu_k(h) \equiv$ mean of $k(h)$
$\sigma^2_k(h) \equiv$ variance of $k(h)$
$\sigma^2_\omega(h) \equiv$ variance of ω
$\rho_k \equiv$ correlation between outcomes $k(1)$ and $k(2)$
$\kappa_k(h) \equiv$ correlation between outcomes $v(h)$ and $k(h)$
$\theta_k(h) \equiv$ correlation between outcome $k(h)$ and ω

Three correlations play a role in the model: ρ_k represents between-system correlations of a given outcome k; $\kappa_k(h)$ represents within-system correlations between economic returns v and another outcome; and $\theta_k(h)$ is the correlation between an outcome of a system and opportunity cost. Summarizing, the model involves five parameters of the distribution of ω, the means and variances of $v(1)$ and $v(2)$, and their correlation. In the case of outcome variables based on v, no additional parameters are required. For each non-economic outcome variable, there are seven additional parameters, a mean and a variance for each system, and the three correlations defined above. Thus, with n non-economic indicators, the total number of parameters is equal to $5 + 7n$. This relatively small number of parameters makes this model easy to interpret and convenient for analysis of parameter uncertainty.

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

System Design. The first step in using TOA-MD is the definition of the population for analysis, including any appropriate stratifications; e.g., by geographic or socioeconomic criteria. The second step is the description of the systems being modeled and identification of the impacts to be quantified. The third step is the identification of the information needed to estimate the model's parameters. How this step is implemented will depend on the details of the systems being modeled. Since the model parameters are the moments of outcome distributions, the ideal data would come from a stratified random sample from sub-populations of adopters and non-adopters of the technology.

In contrast to the stylized case of a discrete technology such as a new seed variety, most technologies are packages of practices that are adopted in varying combinations and degrees by farmers (indeed, even new seed varieties are usually combined with other inputs in this manner). An important feature of the TOA-MD model is that it allows a "technology" to be represented realistically as a set of management practices distinguished by the use of certain technological components, but all farms need not be using the "technology" in precisely the same manner. This is possible because in the TOA-MD the only distinguishing feature of each "system" is that it gives rise to a different expected return for each producer, and thus a different distribution of returns in the population. This characterization is appropriate for the agriculture-aquaculture systems promoted by the Development of Sustainable Aquaculture Project (DSAP) that involve a package of management practices that are implemented in varying degrees and combinations by farmers.

The model utilizes the following types of data:

- Population means and variances by crop, aquaculture, and livestock activity of production, output price, and cost of production.
- Population means and variances of environmental and social outcomes associated with each system.
- Correlations between system returns and environmental and social outcomes.
- Population means and variances of farm household characteristics (farm size, pond size, household size, off-farm income).

3. Description of the IAA farming system and capacity development

The basic principle of IAA is to enhance on-farm resource-use efficiency and productivity via the integration of resource flows between terrestrial and aquatic subsystems. IAA moves from a fishpond focus to a whole-farm perspective, utilizing ponds and paddy fields by optimizing management of on-farm resources. IAA is thus a knowledge-intensive, holistic approach that integrates numerous component technologies within systems management. IAA and its history of development in Bangladesh is described in Jahan, Beveridge, and Brooks (2008).

Building on the technology base from earlier projects, DSAP aimed at improving resource-use efficiency and sustainably increasing productivity at the farm level through IAA. The various alternatives for IAA can be combined selectively depending on farmer conditions. Given the knowledge-intensive nature of the technologies, DSAP utilized a strategy of decentralized, local-level, long-term training. Covering 34 of the 64 districts in the country, the project and its follow up lasted from 2001 through 2005, with a total budget of US$5.5M. The project provided multiple training opportunities to over 63,000 farm households and reached many more through other communication strategies. Farmers were exposed to a basket of 19 technologies and management practices, selecting from them according to their particular needs and preferences. Project monitoring reports document widespread adoption of many of the component technologies, and various studies have examined the additional profitability achieved (Jahan, Ahmed, & Belton, 2010; Jahan, Beveridge, & Brooks, 2008; Jahan & Pemsl, 2011). Widely adopted technologies include IAA-based carp polyculture, carp-shrimp polyculture, and nursery management practices in ponds and rice fields (DSAP, 2005).

The WorldFish Center applied a 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; Lightfoot, Prein, & Lopez, 1994). Thus 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 and transfer that is based on farmer-scientist research partnerships. The approach implies the use of IAA, in which existing resources (in the form of organic wastes and byproducts) from on and around the farm are utilized as nutrient inputs to the pond and to other enterprises, reducing the need for purchase of off-farm inputs such as inorganic fertilizers, and thereby reducing production costs, maximizing the use of on-farm resources, and leading to improved environmental sustainability (Lightfoot et al., 1993; Lightfoot & Noble, 2001). This approach was implemented by research extension teams under the farmer-scientist research partnership concept. The relationships established with farming communities under the project also facilitated the collection of longer-term monitoring data on technology adoption and impact, which was collected using the RESTORE methodology (Lightfoot et al., 2000).

4. Data and methods

The first step in using the TOA-MD model is definition of the population for analysis. The population of this study represents the small-scale aquaculture farms of Mymensingh, Comilla, Magura, and Bogra districts. The economy of the study locations is predominantly agrarian and characterized by small-scale and fragmented farming. Agriculture is predominantly semi-subsistence level, and land productivity is generally low, resulting in widespread poverty among the population engaged in the sector. Current estimates of national rural poverty rates stand between 53 percent and 44 percent (IFAD, 2010). Agriculture in the study location is characterized by farms that are smaller than 0.48 ha, on average (Hossain & Bayes, 2009), and grow mixed crop systems of rice, oil seed, pulses, and vegetables. The aquaculture farms of these districts are generally characterized by low integration, which could be improved by training support on IAA. Estimates show that the country has 265,000 ha of small-scale homestead ponds (Belton et al., 2011). The total pond area in the above districts is recorded as approximately 34,000 ha (DOF, 2008).

The second step to using TOA-MD is the description of the systems being modeled and the identification of the impacts to be quantified. Obtaining data to provide accurate, unbiased estimates of System 1 and System 2 parameters (means, variances, and correlations) is one of the main challenges in impact assessment with TOA-MD. As described below, the survey data of this study categorize the farms according to a) whether they did or did not receive training support, and b) the level of utilization of IAA on the farm. Based on these categorizations, systems defined in this study are as follows:

- **System 1:**
  Farms with no training support and low level and quality of integration of aquaculture and agriculture. The level of integration is defined by the number of bio-resource flows in the farm among the different farming enterprises, where three or fewer bio-resource flows are considered to be the low-integration case.
- **System 2:**
  Farms with training support and a highly integrated system among the crop-based systems of rice, vegetables, and other crops with livestock, poultry, and ponds. More than three bio-resource flows among the enterprises is defined as the high-integration case.

The estimated impact indicators of IAA technology development and dissemination are as follows:

- **Mean farm income and per capita income:**
  The mean farm income (gross income) in the study area is about US$1500/yr, while the per capita income is about US$356/yr. Fish culture contributes about 16 percent of farm income and 11 percent of total annual income (Jahan et al., 2011).
- **Poverty rate:**
  An estimated 45–50 percent of Bangladesh's 150 million people reportedly live below the international poverty line of US$1.25 a day (Index Mundi, 2012). Considering the 2005 conversion value of US$1.25/day PPP equivalent to BDT 31.86 (Bangladesh Taka) and the 2005 exchange rate of BDT 62 per US dollar, the poverty line was set as US$187 per year.
- **Calorie consumption:**
  We use food consumption as a proxy for nutrition. The recent Household Income and Expenditure Survey presents the food energy received from individual food items in the form of calories (HIES, 2005). On average, rural households received 2,253 kilocalories from food items, where fish contributed 51.6 kilocalories (BBS, 2007). We recognize that total calories are an imperfect measure of food and nutrition security and that macro- and micronutrients play important roles (Kawarasuka & Bene, 2010; Roos et al., 2007).

The third step to using TOA-MD is to identify the information needed to estimate the model parameters. The data used in this study are from three separate surveys (see Table 1). The first is the baseline survey of participating households. The second is the project end-line survey of the same households. The third is the control survey of households that did not participate in the project. See Jahan and Pemsl (2011) for a description of the survey sampling procedures.

Table 1. DSAP surveys used in the analysis.

Survey[1]	Total households	Households with low integration of IAA practices[2]	Households with high integration of IAA practices[3]
Project baseline	260	58	202
Project end line	260	14	246
Control	126	23	103

Notes:

1. Project baseline taken 2002/2003 in four representative districts illustrated in Figure 1. Project end-line survey taken in 2005/2006. Control survey taken in 2003/2004.
2. Three or fewer managed resource flows.
3. More than three managed resource flows.

During the three-year life of the project, the baseline survey households were monitored for adoption of IAA practices. Column two of Table 1 shows that 44 farm households in the project baseline survey shifted from low to high integration, an adoption rate of 76 percent. That shift shows also in the third column, where all farmers had received training on IAA at project end. The participating farmers were trained to use record books provided to them to monitor all on-farm production activities over the entire duration of the study. Research assistants visited each family on a bi-monthly basis to collect the information, help complete the record books where necessary, and answer questions. In addition to the production monitoring, respondents kept daily records of what they and their households ate in a consumption diary. The monitoring survey used the RESTORE format developed by WorldFish. The RESTORE format covers information pertaining to IAA farms, such as fish pond yield, total farm productivity, total farm income, recycling of farm outputs, number and kind of resources being recycled, diversification of farm enterprises, number of managed enterprises, and improved soil fertility, among other indicators.

For the analysis, we created a data set of System 1 farmers consisting of the 58 low-integration households from the project baseline survey and 23 from the control sample survey, for a total of 81. The System 2 farmers were the 246 with high integration and training in the end-line survey. We then stratified the two systems into groups, with small and medium farms being those households with land up to one hectare and large farms being those with more than one hectare. The objective of this stratification was to see the effect of farm size on IAA adoption. The summary statistics from the two stratifications are presented in Table 2. The comparisons of the systems clearly show that households in System 1 were managing fewer resource flows and had a lower income from farm enterprises, as well as lower food consumption. Non-farm income is the only measure that is greater in System 1 than in System 2.

Table 2. Summary statistics from the sample data (means).

	System 1			System 2		
Strata	Small and Medium	Large	All	Small and Medium	Large	All
Number	57	24	81	130	116	246
Farm size (ha)	0.50	1.88	0.91	0.59	2.11	1.31
Crop income ($/yr)	77	148	97	402	818	570
Animal income ($/yr)	14	22	15	37	59	42
Fish income ($/yr)	51	71	55	108	269	180
Non-farm income ($/yr)	739	1298	863	437	1013	799
Household members	5.20	5.96	5.41	5.96	6.91	6.33
Fish consumption (kcal/person)	30.6	34.2	31.7	40.4	50.2	49.0
Food consumption (kcal/person)	2129.3	2229.8	2141.5	2324.3	2501.4	2475.8
Resource flows	2.32	2.08	2.11	8.87	10.39	9.61

Source: Authors' calculations from DSAP survey data.

As discussed above, the TOA-MD model used in this study contained five subsystems, which included aquaculture, rice, vegetables, other crops (pulses, spices, etc.), and animals (cows and poultry). The following data were used to assess the impact of IAA technologies by systems and strata:

- Farm level data, including total farm size, average farm and pond size, average family size, and non-farm income of the households.
- Total returns from each subsystem (US dollars per household per year).
- Total costs of production of each subsystem (US dollars per household per year).
- Resource flows (the recycling of farm outputs, counted as the number of material types being recycled)

5. Results

The results of the TOA-MD areas of analysis are shown in the figures and summarized in Table 3. Figure 2 presents the simulated adoption curves for small and medium farms and for large farms, as described in Table 2 above. The x-axis represents the adoption rate, and the y-axis shows the opportunity costs of return from System 1 and System 2. Recall that the calculation of opportunity cost is the cost of remaining in System 1. Thus when the cost is negative, farmers will switch to System 2. The points on the curve to the left of where it crosses the x-axis show the percentage of switching farms with gains, and those on the right show those with losses greater than the amount shown on the vertical axis. The positive variance of the distribution of returns is the demonstration that farms in the population are not exactly the same and are not managing the farming system in the same way.

Note that in Table 1, there were 202 high-integration farms in the baseline survey. This number grew to 246 in the end-line survey. The average resource flows among these grew from 6.6 to 9.6 during the life of the project. Figure 2 shows the predicted adoption rates for IAA technologies for the total System 2 sample, and the size stratifications are about 91 percent. This figure is similar to the actual adoption rate of 246 out of 250. Table 3 presents the change in mean farm incomes for adopters and the whole population, illustrating the sizable economic benefits to farmers that are adopters.

Figure 3 illustrates a different look at the data, a "before and after" comparison of the project farms that were originally classified in System 1. In this comparison, the predicted adoption rate is lower, at approximately 78 percent. This may reflect a reduced potential for managed resource flows due to limited farm enterprises or farm management time available to the farm family. The simulated rate is a good approximation of the observed adoption rate of 79 percent (46 out of 58).

Figure 4 presents the predicted poverty rates in relation to the adoption rate of IAA. The y-axis indicates the poverty rate, and the x-axis shows the corresponding adoption rate of IAA. The poverty rate is expressed as the percentage of the farm population living on less than US$1.25 a day. At zero adoption, small and medium farms have a poverty rate of 63 percent, while the rate for large farms is considerably lower at 43 percent. The average figure of 53 percent of the population in poverty is close to national figure of about 51 percent. According to the analysis, the introduction of IAA reduces poverty for IAA adopters, as the poverty rates fell an average of 16 percent. Thus we can see that investment in IAA improves incomes beyond simply income from fish. For the entire population of adopters and non-adopters, the decline in the poverty rate was 15 percent (Table 2).

Figures 5 and 6 show the impacts of IAA adoption on fish and food consumption. The vertical axis shows fish or food consumption measured in kilocalories per person per day. Figure 5 shows fish consumption not significantly different between the two groups of farms. Starting from a fairly low base, however, consumption for adopters in both groups and among the whole population grew more than a third. Adoption results in significantly increased fish consumption. We know from nutrition research that fish can play a significant role in nutrition. The contribution of fish to protein and micronutrients in the diet is significant (Roos et al., 2007).

Figure 6 also shows that food consumption is not significantly different between the two groups. It also shows that food consumption hardly grew as a result of adoption, increasing by only 7 percent among adopters. That the significant increase in fish consumption is not reflected in food consumption growth illustrates that fish contributes few calories to the daily diet. A more important measure of the contribution of fish to the diet would be a measure of animal protein or micronutrients.

6. Conclusions

This paper demonstrates the use of TOA-MD methodology to evaluate the impacts of integrated aquaculture and agriculture technology using data from small-scale aquaculture farms in Bangladesh. The TOA-MD approach offers a rapid, integrative analysis for estimating adoption and possible impact on indicators such as poverty and nutrition, measured in this case by food consumption. The use of TOA-MD in the present study predicts an adoption rate of about 91 percent, close to the adoption rate observed in the study population. This adoption rate indicates significant potential for investments in diffusing IAA technologies. Farms in Bangladesh are intensively managed, and farmers face constraints in obtaining external inputs. The packaging of frequent follow-up training with self-monitoring shows that farmers with training tend to add the management of additional resource flows and manage those flows more effectively. The IAA concepts are clearly attractive to farmers as a means of increasing the productivity of and thus the revenues from various enterprises. It remains unclear how well the adoption has been maintained in the years since the end-of-project survey. A follow-up survey was implemented in 2012. Analysis of that data should provide insights into whether the training effect was durable and whether farmers maintained the increased number of managed resource flows.

The prediction of investment outcomes is highly relevant to agencies interested in development. For those agencies interested principally in poverty reduction, the potential achievements from investing in this type of project are fairly modest, with predicted reductions in the poverty rate of around 15 percent. Thus, for a project with ambitious poverty-reduction goals, the lesson from the analysis is that IAA by itself is not sufficient.

For those interested in food security and nutrition, the results are also interesting. Fish consumption grew significantly. Using fish consumption as a proxy for nutrient security, investments in IAA may provide significant improvements. The potential impact on total food consumption is less significant. For those interested in investments to increase food consumption, the set of IAA practices is probably not sufficient. Given that incomes grew considerably, the project designer should contemplate different or additional activities that would improve nutrition education or dietary practices to encourage the adopting households to retain and consume a larger share of the food produced on the farm or to use the increased income from its sale to purchase complementary foods.

The development and application of relatively simple and reliable methods for assessing ex-ante impacts of adoption of IAA technologies at the household and population level are extremely important in order to provide appropriate messages to managers and policymakers. The TOA-MD method uses a small sample of an existing data set to illustrate the potential of quickly and relatively inexpensively producing an analysis of the potential of development investments. It does this by predicting adoption and outcomes. The method highlights the obvious: Not all farmers are alike, and they separate themselves into adopting and non-adopting groups. Further, the impacts of adopting are correlated with the adoption decision, fundamental aspects of the rural development process that are ignored in the more frequently used methods of impact assessment.

References

Antle, J.M. 2011. Parsimonious technology impact assessment. *American Journal of Agricultural Economics*, 93(5): 1292–1311.

Antle, J.M., and R.O. Valdivia. 2011. TOA-MD Version 5: Minimum-data tradeoff analysis model. Retrieved from www.tradeoffs.oregonstate.edu

Antle, J.M., B. Diagana, J.J. Stoorvogel, and R.O. Valdivia. 2010. Minimum-data analysis of ecosystem service supply in semi-subsistence agricultural systems: Evidence from Kenya and Senegal. *Australian Journal of Agricultural and Resource Economics*, 54: 601–617.

Antle, J.M., and R. Valdivia. 2006. Modelling the supply of ecosystem services from agriculture: A minimum-data approach. *Australian Journal of Agricultural and Resource Economics*, 50: 1–15.

BBS (Bangladesh Bureau of Statistics). 2007. *Statistical year book of Bangladesh*. Dhaka, Bangladesh: Bangladesh Bureau of Statistics, Planning Division, Ministry of Planning.

Bangladesh Planning Commission. 2005. *Unlocking the potential: National strategy for accelerated poverty reduction*. Published by Planning Commission, Government of People's Republic of Bangladesh.

Belton, B., M. Karim, S. Thilsted, K.M. Jahan, W. Collis, and M. Phillips. 2011. Review of aquaculture and fish consumption in Bangladesh. *Studies and Reviews 2011-53*. The WorldFish Center, November 2011.

de Janvry, A., A. Dustan, and E. Sadoulet. 2010. *Recent advances in impact analysis methods for ex post impact assessments of agricultural technology: Options for the CGIAR*. Prepared for the Standing Panel on Impact Assessment, CGIAR Science Council. 47 pp.

Dey, M.M., F.J. Paraguas, P. Kambewa, and D.E. Pemsl. 2010. The impact of integrated aquaculture-agriculture on small-scale farms in Southern Malawi. *Agricultural Economics*, 41: 67–69.

Dey, M.M., P. Kambewa, M. Prein, D. Jamu, F.J. Paraguas, D.E. Pemsl, and R.M. Briones. 2006. Impact of development and dissemination of integrated aquaculture-agriculture (IAA) technologies in Malawi. *WorldFish Center Quarterly*, 29(1&2): 28–35.

DOF (Department of Fisheries). 2008. *Fishery statistics year book of Bangladesh 2007/08*. Bangladesh: Fisheries Survey System, Department of Fisheries.

DSAP. 2005. Final report of the development of sustainable aquaculture project (USAID Cooperative Agreement 388-A-00-00-00068-00). Dhaka, Bangladesh: The WorldFish Center. 41 pp.

FAO. 2006. *The state of food insecurity in the world*. Rome, Italy: FAO.

Hossain, M., and A. Bayes. 2009. *Rural economy and livelihoods: Insights from Bangladesh*. Dhaka, Bangladesh: AH Development Publishing House.

HIES. 2005. *Report of the household income and expenditure survey (HIES)*. Dhaka, Bangladesh: Bangladesh Bureau of Statistics (BBS), Ministry of Planning.

IFAD. 2010. *Rural poverty in Bangladesh*. Retrieved from http://www.ruralpovertyportal.org/web/guest/country/home/tags/bangladesh

Index Mundi. 2012. *Bangladesh population below poverty line*. Retrieved from http://www.indexmundi.com/facts/indicators/SI.POV.DDAY

Jahan, K.M., and D.E. Pemsl. 2011. The impact of integrated aquaculture-agriculture on small-scale farm sustainability and farmers' livelihoods: Experience from Bangladesh. *Agricultural Systems*, 104: 392– 402.

Jahan, K.M., M. Ahmed, and B. Belton. 2010. The impacts of aquaculture development on food security: Lessons from Bangladesh. *Aquaculture Research*, 41(4): 481–495.

Jahan, K.M., M. Beveridge, and A.C. Brooks. 2008. Impact of long-term training and extension support on small-scale carp polyculture farms of Bangladesh. *Journal of the World Aquaculture Society*, 39(4): 441–453.

Kawarazuka, N., and C. Bene. 2010. Linking small-scale fisheries and aquaculture to household nutritional security: An overview. *Food Security 2*(4): 343–357. DOI: 10.1007/s12571-010-0079-y

Lightfoot, C., and R.P. Noble. 2001. Tracking the ecological soundness of farming systems: Instruments and indicators. *Journal of Sustainable Agriculture*, 19(1): 9–29.

Lightfoot, C., M.A.P. Bimbao, T.S. Lopez, F.F.D. Villanueva, E.L.A. Orencia, J.P.T. Dalsgaard, F.C. Gayanilo, M. Prein, and H.J. McArthur. 2000. *Research tool for natural resource management, monitoring and evaluation (RESTORE) volume 1: Field guide*. Penang: ICLARM.

Lightfoot, C., M. Prein, and T. Lopez. 1994. Bio-resource flow modeling with farmers. *ILEIA Newsletter, 10*: 22–23.

Lightfoot, C., M.P. Bimbao, J.P.T. Dalsgaard, and R.S.V. Pullin. 1993. Aquaculture and sustainability through integrated resources management. *Outlook on Agriculture 22*(3): 143–150.

Maredia, M.K. 2009. Improving the proof: Evolution of and emerging trends in impact assessment methods and approaches in agricultural development. IFPRI Discussion Paper 00929. 39 pp.

Mazid, M.A. 1999. *Rural and coastal aquaculture in poverty reduction*. Proceedings of a seminar organized on the occasion of Fish Week 1999. Ministry of Fisheries and Livestock, Bangladesh.

OECD. n.d. *The Paris declaration on aid effectiveness and the Accra agenda for action*. 23 pp. Retrieved from http://www.oecd.org/dataoecd/11/41/34428351.pdf

Roos, N., M.A. Wahab, C. Chamnan, and S.H. Thilsted. 2007. The role of fish in food-based strategies to combat vitamin A and mineral deficiencies in developing countries. *Journal of Nutrition*, 137: 1106–1109.

Russell, A., P. Grotz, S. Kriesemer, and D. Pemsl. 2008. Recommendation domains for pond aquaculture: Country case study: Development and status of freshwater aquaculture in Malawi (WorldFish Center Studies & Reviews No. 1869). Penang, Malaysia: The WorldFish Center. 52 pp.

Walker, T., J. Friday, M. Casimero, R. Dollentas, A. Mataia, R. Acda, and R. Yost. 2009. The early economic impact of a nutrient management decision support system (NuMaSS) on small farm households cultivating maize on acidic, upland soils in the Philippines. *Agricultural Systems, 101*: 162–172.

Walker, T., M. Maredia, T. Kelley, R. La Rovere, D. Templeton, G. Thiele, and B. Douthwaite. 2008. S*trategic guidance for ex post impact assessment of agricultural research*. Report prepared for the Standing Panel on Impact Assessment, CGIAR Science Council. Rome, Italy: Science Council Secretariat.

Walker, T., and C. Crissman. 1996. *Case studies of the economic impact of CIP-related technologies*. Lima, Peru: International Potato Center (CIP).

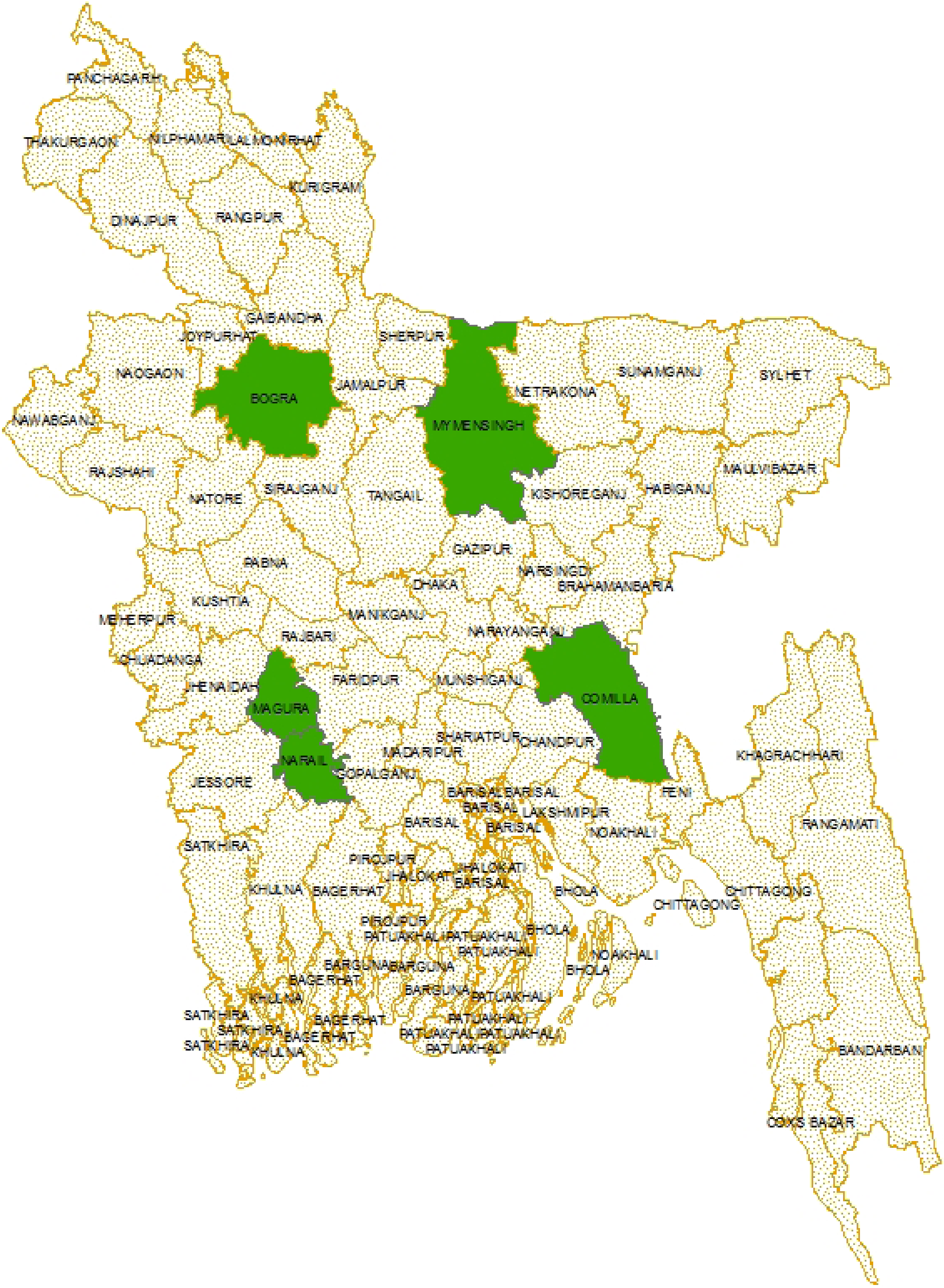

Figure 1. Map of Bangladesh and the DSAP survey study areas: My Magura, and Bogra.

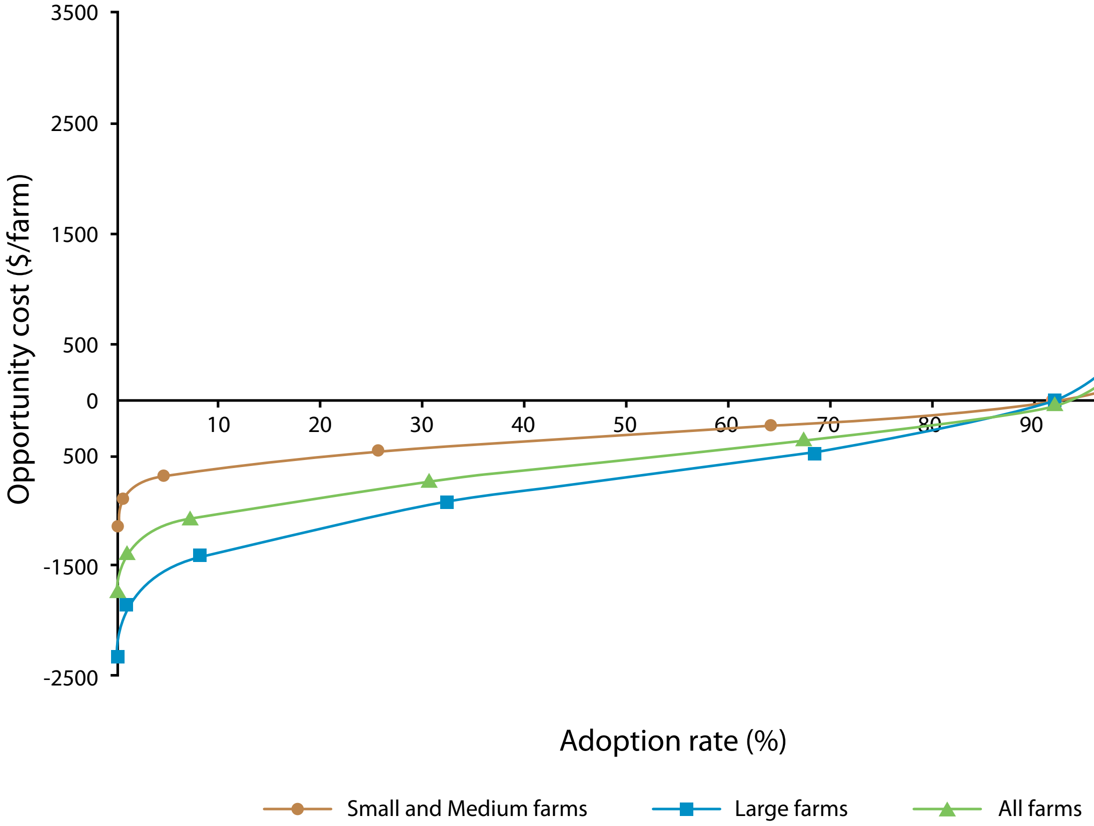

Figure 2. Adoption rate and opportunity cost of adopting IAA in Bangladesh.

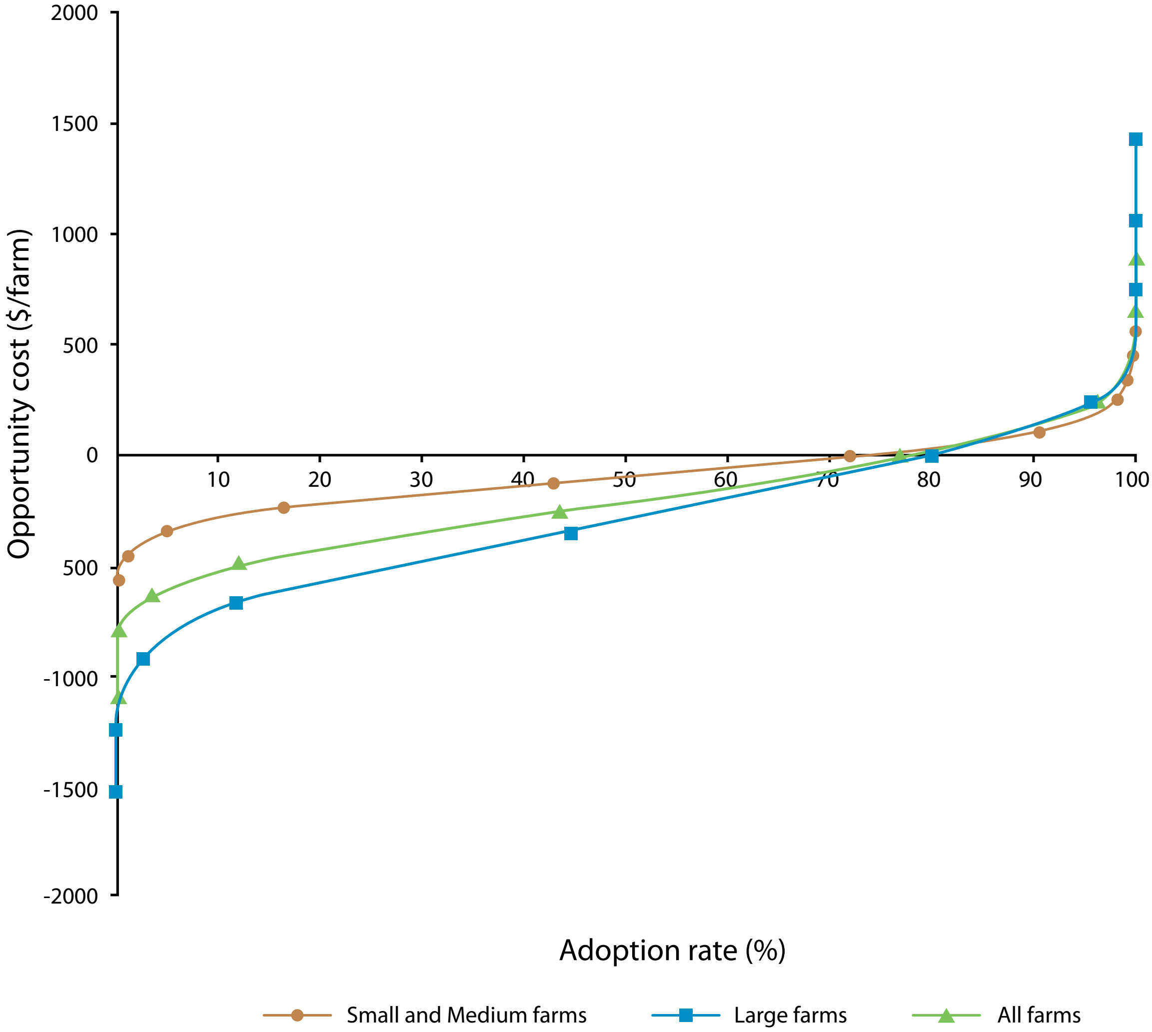

Figure 3. Adoption rate and opportunity cost of IAA adoption after the DSAP project among project farms originally classified as low integration.

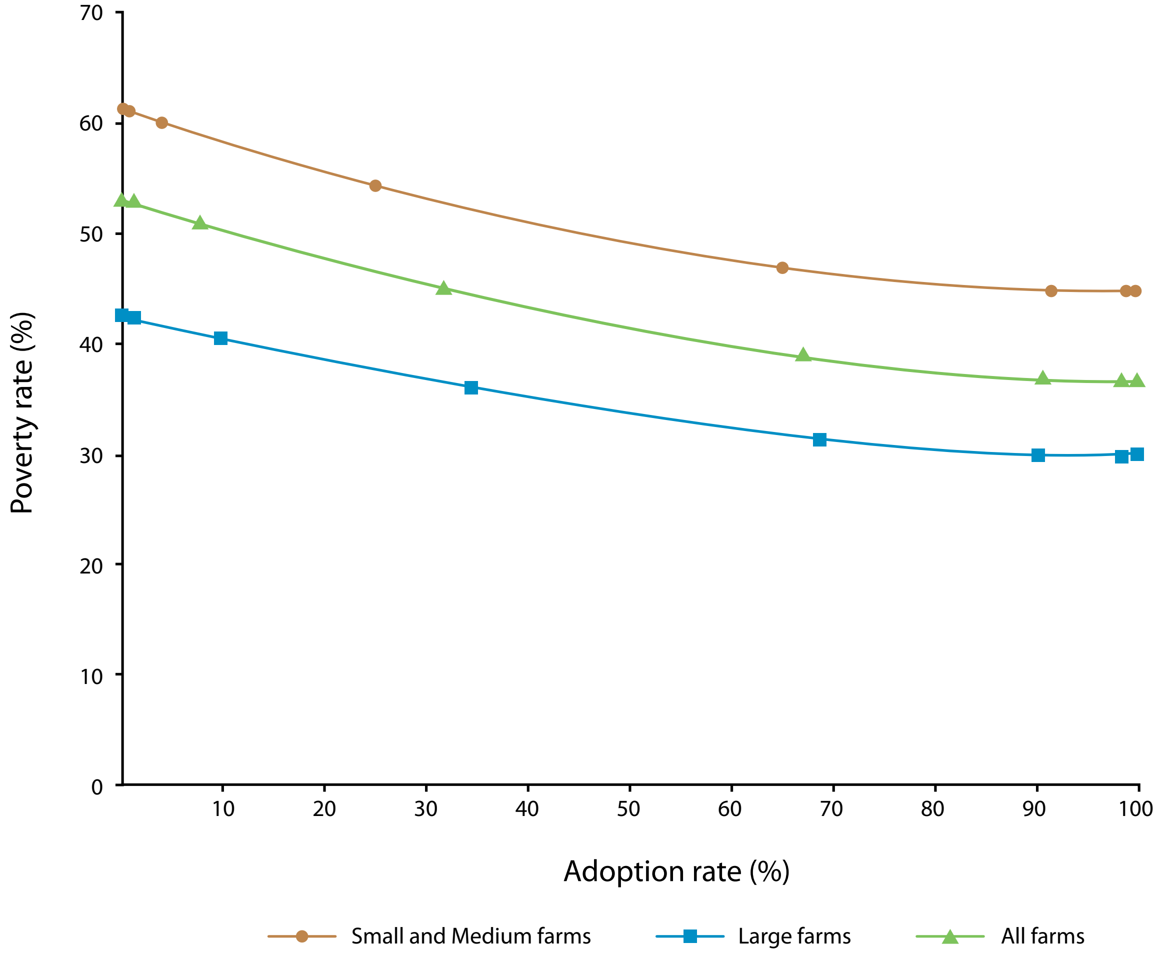

Figure 4. Poverty rate and adoption rate of IAA, Bangladesh.

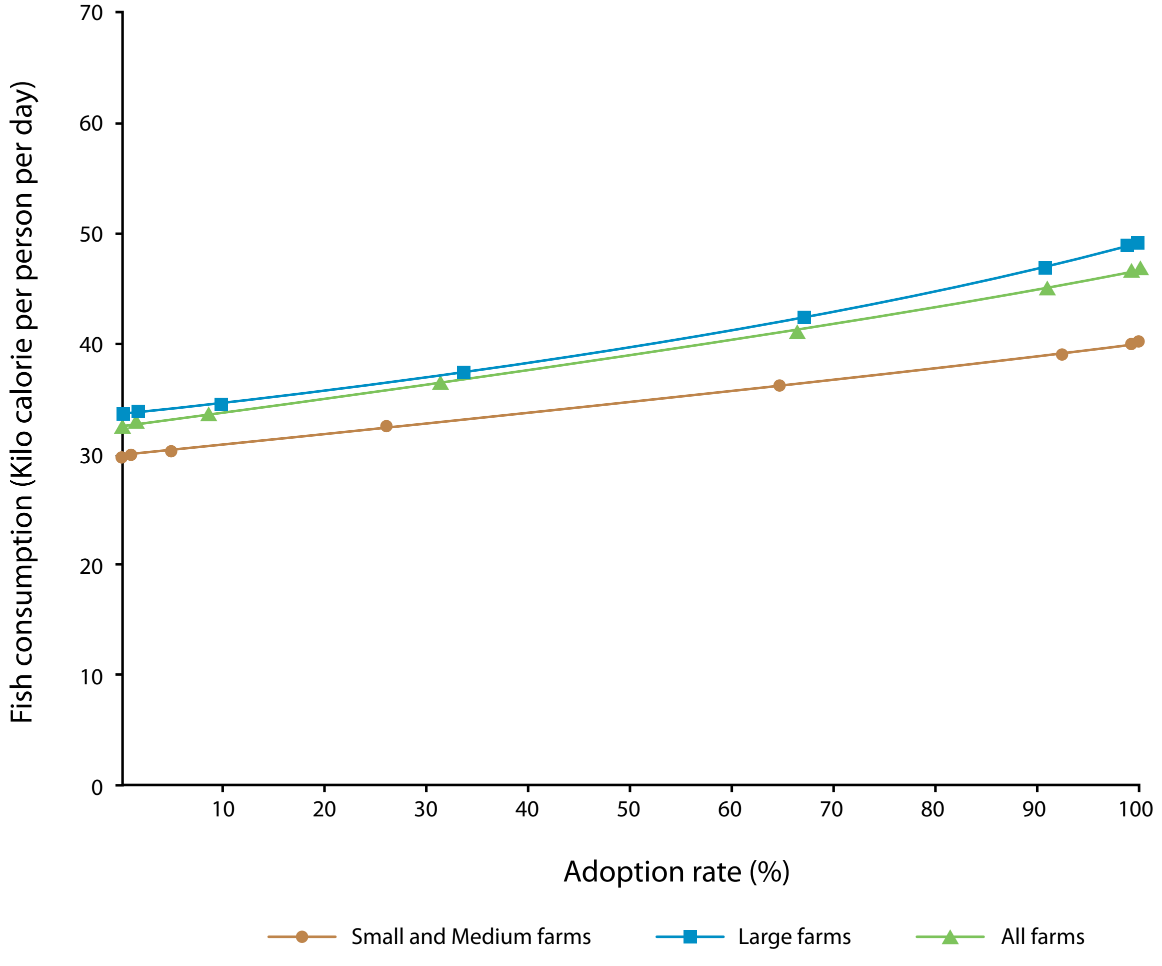

Figure 5. Fish consumption and adoption of IAA, Bangladesh.

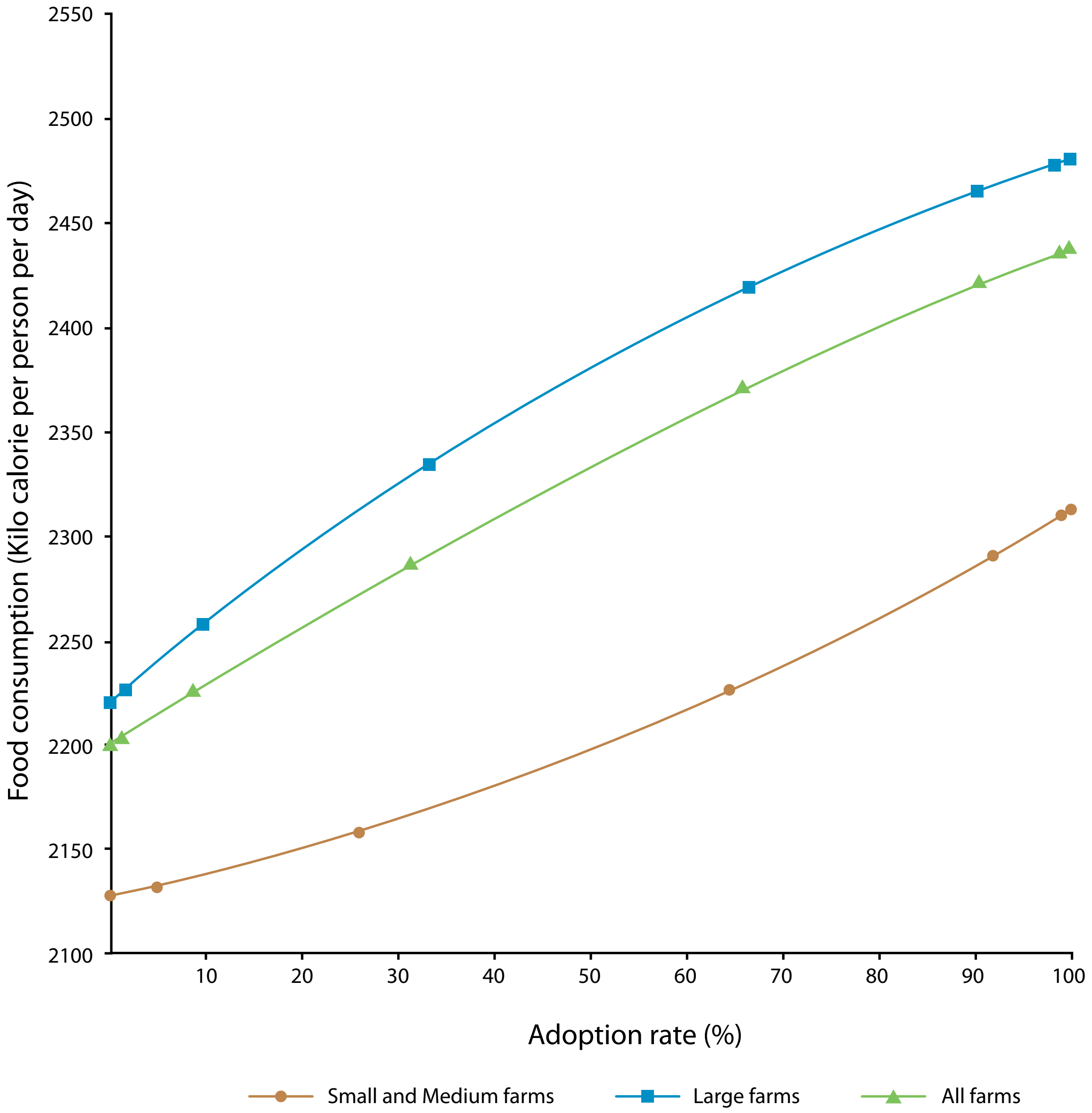

Figure 6. Food consumption and adoption of IAA, Bangladesh.

Table 3. Summary results of IAA adoption in Bangladesh.

Strata Farms	Adoption rate (%)	Ave. farm income ($/year)			Poverty rate (%)			Fish consumption (kilo calorie/person/day)			Food consumption (kilo calorie/person/day)		
		Base (no adoption)	% Change for population	% Change for adopters	Base (no adoption)	% Change for population	% Change for adopters	Base (no adoption)	% Change for population	% Change for adopters	Base (no adoption)	% Change for population	% Change for adopters
Small and medium	91.74	129	245	277	63	-16	-18	31	29	32	2129	8	9
Large	90.13	230	302	349	43	-14	-16	34	40	44	2230	12	10
All	90.56	171	277	318	53	-15	-17	33	38	41	2204	11	10

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