

**DETERMINING HIGH POTENTIAL AQUACULTURE PRODUCTION AREAS  
- ANALYSIS OF KEY SOCIO-ECONOMIC ADOPTION FACTORS**

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**ABSTRACT**

Global aquaculture production increased with an average rate of 10% per year since 1990 and 90% of aquaculture production comes from developing countries thus providing livelihood and income especially to marginal groups who have limited access to resources such as agricultural land and financial capital. Geographical information systems (GIS) based decision support models can facilitate the prioritizing of national research, development and extension strategies and targeting of development assistance for aquaculture because they can provide information to stakeholders as to where and under what conditions certain aquaculture technologies would be feasible. Factors that determine the adoption of aquaculture technologies by farmers include agro-ecological (rainfall, temperature, soil type, slope), socio-economic (land, labor, capital, infrastructure, inputs), and institutional characteristics (extension services, producers' organizations). While maps can be used to display the agro-ecological factors, many important socio-economic and institutional variables are not explicitly spatial (such as household land holdings or access to education and credits). To enable the integration of socio-economic variables in GIS models, we suggest a methodology comprising of four stages: (1) identification of key factors for successful adoption of target technologies on the micro-level, (2) development of indicators on the meso-level, (3) generation of geo-referenced meso-level indicator data sets for the target area, and (4) assignment of ranking/weights to the indicators. The paper outlines the conceptual framework applied and highlights some of the inherent methodological challenges. Results of the adoption analysis for aquaculture in Bangladesh and Malawi, representing different levels of aquaculture production intensification, are presented and discussed.

**Keywords:** Adoption of aquaculture, developing countries, decision support model, GIS

**INTRODUCTION**

Fish provide more than 20% of the animal protein intake per capita for more than 2.6 billion people, most of them living in developing countries (FAO 2004). Aquaculture and fishery related activities thus provide livelihood and income especially to marginal groups who have limited access to resources such as agricultural land and financial capital. While production of inland and marine capture fisheries have remained stable since 1998, aquaculture production increased with an average rate of 10% per year since 1990. Aquaculture has become the fastest growing food producing sub-sector in the world and today some 90% of aquaculture production takes place in developing countries (FAO 2004). Positive impact from aquaculture production can arise at different levels: i) higher productivity, income and better livelihoods at the producer level, ii) increase supply of fish and a reduction in prices at the consumer level, and iii) increase in trade and export of fish as well as employment generation that benefit overall development (Ahmed and Lorica 2002, Dey et al. 2006).

Geographical information systems (GIS) based decision support models can facilitate the prioritizing of national research, development and extension strategies and targeting of development assistance for aquaculture because they can provide information to stakeholders as to where and under what conditions certain aquaculture technologies would be feasible<sup>1</sup>. Target stakeholders include government and non-government agencies responsible for promoting aquaculture development at the national level and in donor agencies concerned with investment priorities.

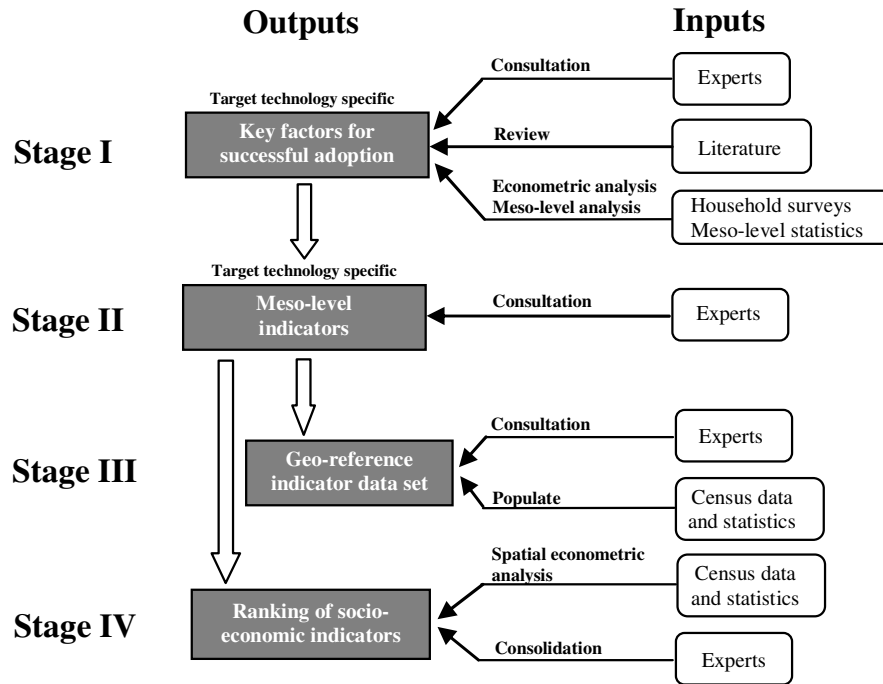
To adequately assess the suitability of a specific location for aquaculture production, agro-ecological (including agro-climatic and bio-physical variables such as rainfall, temperature, soil type, slope), socio-economic (availability of land, labor, capital, infrastructure, and inputs), and institutional (access to extension services, producers' organizations) characteristics need to be included. Agro-ecological factors can be incorporated in GIS models in a straightforward manner by generating surfaces of rainfall, soil type, slope, or temperature and subsequent modeling of determining factors such as water availability. Many important socio-economic and institutional variables (such as household land holdings and family labor or access to education and credits), however, are not explicitly spatially distributed and thus the integration of these variables into GIS models requires additional steps. Other socio-economic variables are entirely non-spatial (such as policy settings and extension system) and can only be included in the form of comparative case studies or as a checklist of additional factors that act as driving forces or constraints for aquaculture production. In this paper, we focus on those socio-economic factors that can be included in GIS modeling, while for the remaining factors we aim at developing non-spatial, rule-based decision tools. Despite methodological difficulties, it is important to incorporate socio-economic variables in suitability models to obtain recommendations that go beyond the agro-ecological production potential of a certain location. This is especially important when considering the track record of dis-adopters of new technologies once external (or project) support terminates.

The paper is organized as follows: we first outline the conceptual framework for the incorporation of socio-economic factors in GIS based decision support models and highlight some methodological challenges. After a brief introduction of the data sets that are available for the analysis, descriptive results are presented together with an overview of the national aquaculture sector of Bangladesh and Malawi. We present findings of a literature review of adoption constraints and the results of the micro-level adoption analysis of aquaculture in Bangladesh and Malawi before closing with outlook and conclusions.

## **METHODOLOGICAL FRAMEWORK AND DATA**

### **Methodological framework**

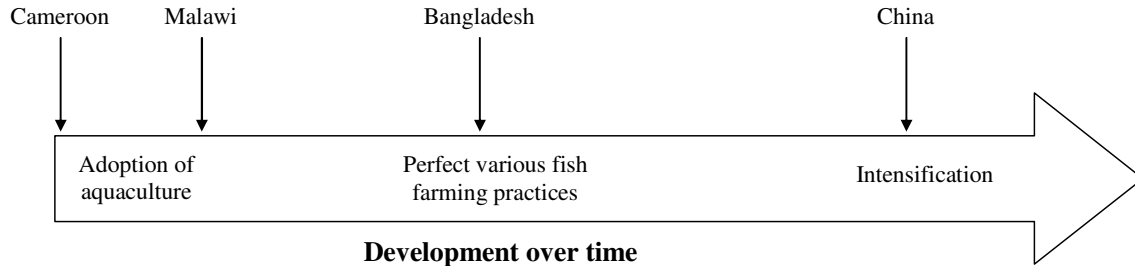
To integrate socio-economic variables in GIS modeling, we suggest a four-stage methodology (Figure 1). In the first stage, key factors for successful adoption of target technologies on the micro-level are identified. Here, we first carried out a literature review of existing studies and then conducted regression analysis using Probit models to identify country specific key adoption factors using household level survey data. To account for the specific conditions, the analysis of aquaculture adoption considers a "yes/no" decision as dependent variable for the African context, while the focus in the two Asian countries is on the degree of intensification (on a continuum from extensive to intensive). To study this aspect, we follow a two-step procedure i.e. to first identify key adoption factors and in a second step analyze what characterizes those adopters that are practicing intensive aquaculture or those farmers who are performing very well.



**Figure 1:** Analysis framework for incorporating socio-economic factors in GIS modeling

Edwards (1993) defined different intensity levels of aquaculture systems. Namely, extensive aquaculture systems without nutritional inputs (yields of 0 – 1 t per hectare and year), semi-intensive systems with supplementary feed and input of mineral fertilizer (resulting in yields of 1 – 15 t per hectare and year), and finally intensive systems (yields > 15 t per hectare and year) with increasing shares of feed up to complete feed, and for higher intensities aeration, recirculation and raceways. In developing countries, extensive, improved extensive and semi-intensive systems are most common while the high intensity systems are certainly not within reach of small-scale producers. However, different aquaculture systems may simultaneously exist in a country or location. Still, the different intensity levels can be considered as development along an evolution or intensification timeline of aquaculture.

As depicted in Figure 2, the most dominant pattern of the current status of aquaculture systems in the four selected countries, correspond to different intensity levels of production. In Cameroon, for example, adoption of freshwater aquaculture is in its infancy and involves only a small number of farmers, whereas in Malawi, adoption of fish farming has already gained momentum and over the past years, the importance and awareness of aquaculture has increased tremendously. In both African countries, aquaculture production is mainly extensive with few external inputs and ponds are a relatively new enterprise in the farming system (Brummett and Williams 2000, Jamu and Chimatiro 2004, WorldFish Center 2005). This is a situation where (potential) adopters of aquaculture are new entrants and hence emphasis will be placed on the question which farmers do adopt aquaculture and which do not (and why) as well as the issue of how (well) aquaculture activities are integrated in the existing farming system (degree of integration with agriculture activities). The integration of aquaculture production is particularly relevant as access to markets is limited and external inputs are not easily available and expensive due to high transportation costs (ibid). In Bangladesh, ponds and water bodies are omnipresent and catch and production of fish has a long tradition and is widespread (Gupta et al. 1999, Alam and Thomson 2001). Currently, catch from inland water bodies can not provide higher quantities of fish to feed the growing population and thus aquaculture is developing fast. In the context of Bangladesh, adoption is thus an intensification of the use of existing ponds rather than digging new ponds.



**Figure 2:** Potential development of aquaculture activities over time

This might involve the use of external inputs (such as fertilizer and feed), as well as (increased) stocking of fish. At the same time, the amount of fish produced exceeds what is or can be consumed by the household or can be sold to neighbors and friends. Thus, factors related to fish marketing need to be considered. In China, aquaculture is characterized by increasing intensification of production which is accompanied by widespread use of external inputs (commercial feed and mineral fertilizer) and production of high value species for local and export markets (CCAP/FFRC 2004). This intensification of production by farmers is largely economy driven, with impetus from policy incentives<sup>2</sup>.

In the second stage, meso-level indicators will be developed based on the results of the regression analysis. In some cases, this will require only the adaptation of measurement units (e.g. household level key factor is the number of years of schooling, while meso-level indicator is the share of farmers having a certain level of education). For other variables, proxies are required that can replace the household level key factors on an aggregated level (e.g. if the availability of family labor is identified as important adoption factor, the prevailing wage rate for unskilled labor can be used as a proxy for labor scarcity). In the third stage of the analysis, the indicators are populated using census data and national statistics (e.g. for population density, land holdings, infrastructure) as well as expert knowledge (e.g. for local preferences and attitudes) to derive a geo-referenced data set of meso-level (e.g. sub-district) indicators for the target model area. This requires that a value for each indicator is allocated for e.g. each sub-district to allow a sufficient resolution of the decision support model. As a final step, spatial econometric analysis of census data and statistics will be used to assign different weights to the meso-level indicators to account for their overall importance in the aquaculture adoption process.

### Data sets available for the analysis

Two different kinds of data sets are required for the analysis: i) household level production data for stage I, and ii) meso-level statistics for stages III and IV. To determine key adoption factors, we use micro-level data on input and output information of aquaculture production and general farm as well as household characteristics. Available household surveys were either conducted by WorldFish Center or other parties.

**Table 1:** Micro-level data sets used for the analysis of adoption determining factors (Stage I)

No.	Data name	Country	Source	Sample size	Season	Adopters (No.)
1	DSAP	BGD	WorldFish Center	987	2003	all
2	FFP	BGD	DoF	951	2003	all
3	IAA	MLW	WorldFish Center	315	2004	166
4	ADiM	MLW	JICA	563	2003	396

For Bangladesh (BGD), the data sets used are a producer survey conducted as part of the WorldFish “Development of Sustainable Aquaculture Project (DSAP)” and the government’s “Fourth Fisheries Project (FFP)” coordinated by the Department of Fisheries in Bangladesh (DoF). In Malawi (MLW), data from a farm-level survey conducted by WorldFish in 2004 for an ex post impact assessment of integrated aquaculture-agriculture (IAA) and micro-level data from a project run by Japan International Cooperation Agency (JICA) called “Aquaculture Development in Malawi (ADiM)” were used (see Table 1). For macro-level information (analysis in stages III and IV) the following data sources will be used: Fisheries Statistical Yearbook of Bangladesh 2005, and the Bangladesh Country Almanac (BCA Version 3.0). In addition, an Upazila (sub-district) level survey was conducted by the DoF in collaboration with the WorldFish Center in 2006 to collect variables directly related to the fisheries and aquaculture sector that are not available from other statistics. The data entry for this information is on-going and analysis will start by the end of 2006. For Malawi, we will use the Integrated Household Survey (IHS) from 2000 and 2005, the traditional authority (TA) level Malawi Atlas of social statistics, and the National Aquaculture Database (that is currently being compiled by DoF and will be completed by end of 2006).

## **RESULTS**

### **Overview of freshwater pond aquaculture in Malawi and Bangladesh**

The fisheries sector in Bangladesh provides income earning opportunities for a large population section and fish is an important part of the diet (annual per capita fish consumption of 14 kg). Bangladesh has extensive water resources in the form of ponds, natural depressions, lakes, canals, estuaries, and rivers that cover about 30% of the country’s total area (FAO 2006). Fish production from freshwater pond aquaculture is an important component in the fisheries sector in Bangladesh, accounting for 42% of the total inland fish production of 1.6 million tons in 2003 (DoF 2005). A large number of different species, both exotic and indigenous, are cultured in freshwater ponds in Bangladesh mainly in polyculture system with Indian and Chinese carps. Despite the high level and recent growth in aquaculture production, there is scope for further extension, as the population is growing and the per capita catches of fish are declining. Because of the high importance of the aquaculture and fisheries sector in Bangladesh, in addition to the government institutions such as the Department of Fisheries and its extension services, a large number of non-governmental organizations (NGOs) are engaged in the field. Field staff of these NGOs provides training or facilitates credits for fish farmers (Hossain 1999, Mazid 2002).

In Malawi, per capita annual fish consumption decreased from 14 kg in 1988 to half that figure in 1998, with a corresponding increase in fish prices, due to over-fishing in the lakes and increase in population (Jamu and Chimatiro 2004). This has worsened food insecurity, especially of the rural population in a country where an estimated 66% of the population does not consume the minimum daily calorie requirement (Jamu and Chimatiro 2004). A presidential initiative was launched in early 2006 to foster aquaculture development in Malawi (DoF 2006). Aquaculture accounted for only about 2% of the total fish production of some 50,000 metric tonnes in 2005 (DoF 2006). However, it significantly contributes to income generation and food security particularly in areas away from the major water bodies (e.g. Lake Malawi, Chilwa, and Malombe and large rivers such as Chire) where fresh fish is not available from the wild. Currently, there are an estimated 4,000 aquaculture adopters in Malawi, almost only pond operators and all applying integrated agriculture-aquaculture (IAA) that is characterized by a high degree of integration into existing farming systems (DoF 2006). Resources (in the form of organic wastes and by-products) on and around the farm are utilized as much as possible as nutrient inputs to the pond and also to other enterprises, leading to improved environmental soundness (Lightfoot et al. 1993, Lightfoot and Noble 2001, Prein 2002). The major fish species for aquaculture in Malawi are different, mainly endemic tilapias (accounting for about 93%), as well as catfish.

Table 2 provides an overview of some descriptive characteristics of aquaculture producers in Bangladesh (data sets 1 and 2) and Malawi (data set 3). Figures are extracted from the micro-level data sets that were available for the analysis. For Bangladesh, the data set covers most parts of the country, while the data set from Malawi includes only respondents from the Southern Region. In general, fish farmers are small-holder farmers (with landholding of 1 or 1.5 ha) who devote part of their agricultural land to aquaculture production. Pond area was on average only 0.1 ha. Aquaculture production mainly relies on family labor and part of the produced fish is home-consumed while the remainder is sold mainly at local markets. Especially in Malawi, fish farming accounts for only a minor share of the total farm income (some 12%), while income from other on-farm activities (crop and livestock production) provides the largest share of total farm income (Dey et al. 2006). In most locations in both countries, ponds are only operated seasonally due to water constraints (see culture period in Table 2). The yields realized are in the magnitude of 2.5 tons per hectare and are at the lower end of semi-intensive production systems.

**Table 2:** Profile of aquaculture adopters (sample averages of household level data sets)

	Unit	Data set 1	Data set 2	Data set 3
Age of household head	<i>years</i>	37.2	34.3	45
Household size	<i>number</i>	5.5	6.1	5
Total land area owned	<i>ha</i>	1.02	1.44	1.98
Per capita annual income	<i>US\$</i>	287	253	64
Area of the pond	<i>ha</i>	0.11	0.12	na
Culture period	<i>months</i>	10.0	10.5	na
Aquaculture yield	<i>kg/ha</i>	2789	2531	na
Share of fish sold	<i>%</i>	50	53	na
Net income from aquaculture	<i>US\$/ha</i>	1260	1728	na

### Findings of literature review of constraints to aquaculture adoption

Adapting the typology used by Harrison et al. (1994) we suggest to group the socio-economic driving or inhibiting forces of aquaculture in four major themes: i) access to resources (land, labour, capital, and knowledge); ii) market demand (existence and functioning of markets); iii) socio-cultural aspects (such as mechanisms of control and decision making and consumer habits and preferences); and iv) effects of technology adoption (e.g. intra-household implications such as change in the allocation of cash or labor). Factors from these major themes are used in our analysis of the socio-economic dimension of aquaculture that focuses on the three following major aspects:

- *adoption* i.e. what factors drive people to dig ponds and start aquaculture;
- *intensification and adaptation* i.e. increase the intensity of production or modify the technology to better suit local/individual conditions; and finally
- *dis-adoption and sustainability* i.e. what production constraints or reasons make fish farmers abandon ponds (e.g. on termination of (project) assistance).

Before analyzing the micro-level data sets, a literature review of constraints to aquaculture adoption in Bangladesh and Malawi was conducted. Table 3 summarizes the factors that were identified as constraints to aquaculture adoption by country. In both countries, the lack of technical knowledge or skills as well as the access to credit is hampering aquaculture adoption.

**Table 3:** Constraints to aquaculture adoption identified from literature review

Bangladesh	Malawi
<ul style="list-style-type: none"> <li>• Multiple ownership of ponds</li> <li>• Inadequate technical knowledge</li> <li>• High prices of feed and other inputs</li> <li>• Lack of high quality fingerlings</li> <li>• Poor road quality</li> <li>• Poor economic ability</li> <li>• Inadequate credit options</li> <li>• Insufficient capital (seed money)</li> </ul>	<ul style="list-style-type: none"> <li>• Water shortage</li> <li>• Lack of technical support</li> <li>• Lack of skills and knowledge</li> <li>• Gap between research and farmers' fields</li> <li>• Absence of economic, legal and administrative environment that encourages entrepreneurship</li> <li>• Access to loans for aquaculture</li> <li>• Inefficient fish marketing structure</li> </ul>

**Sources for Bangladesh:** Ahmed and Rab (1992); Gupta et al. (1992, 1999); Ahmed et al. (1994); Gupta and Rab (1994); Thomson et al. (2005); Lewis (1997) and ADB (2005); **Sources for Malawi:** ADiM (2005); DoF (2006); Kapanda et al. (2003).

In Bangladesh, multiple ownership of ponds potentially creates disputes and inputs for fish production are lacking or only available at high costs and poor infrastructure (roads for transport) was identified as adoption constraint. In Malawi, all aquaculture production is integrated aquaculture-agriculture that does not rely on external inputs such as feed and fertilizer but is based on the use of farm by-products. Further constraints in the context of Malawi are the limited availability of water as well as absence of an institutional environment that encourages entrepreneurship.

**Results of adoption analysis**

In interviews conducted for the ADiM study in Malawi, respondents were asked about major objectives for fish farming. The three most common answers were “fish is source of protein” (mentioned by 94.9% of the respondents), “fish farming is income generation option” (93.6% of interviewees) and third most importantly that “fish provides diversification of food sources” (44.9%), reflecting a combination of the first two objectives (ADiM 2005). The major reasons to not adopt fish farming (stated by non-adopters) were lack of information on fish farming (26%), not having access to land (19%), and lack of money (10% of respondents). On the other hand, ex-fish farmers stated they mainly stopped fish farming because of flooding (17%) and loss of fish (24%). Table 4 below presents the major sources of fish farming information for adopters and ex-adopters of aquaculture interviewed for the ADiM study. Most strikingly, farmers who have dis-adopted fish farming, had much lower exposure to project and extension staff and also fewer discussions with and observations from neighbors. The high figure for information from the radio is due to an extension program on fish farming via the radio in Malawi funded by the German gtz.

**Table 4:** Major sources of information for fish farming in Malawi

Sources of information	Fish farmer (%)	Ex fish farmer (%)
Discussion with neighbors	26.1	15.5
Observation from neighbors	40.0	27.6
Fisheries extension officer	57.7	36.2
Project (NGO)	25.3	3.5
Radio	80.9	86.2

Source: ADiM 2005

**Table 5:** Factors determining adoption of aquaculture production in Malawi (adopters vs non-adopters)

	Data set 3	Data set 4
Age of household head (Years)	0.07 ***	0.02 ***
Gender of household head (dummy, 1 for male)	0.23	0.36 *
Availability of water from spring (dummy)	na	0.49 *
Groundwater seepage – dambo areas (dummy)	na	0.38 ***
Number persons trained in IAA per HH	0.46 ***	na
Farm area	0.15 **	0.03
Access to extension	0.62 ***	na
<i>Log likelihood</i>	-154.78	-253.3

Note: Dependent variable = 1if adopter, 0 if non-adopter. \*, \*\*, \*\*\* stand for 0.1, 0.05, 0.01 level of significance.

Tables 5 and 6 provide the factors that in the regression analysis significantly explained the adoption of aquaculture or the continued adoption or increased integration of fish farming with other farm activities, respectively<sup>3</sup>. The significance of the household head age could mean that more experienced farmers are more likely to engage in new farm enterprises, or that initial capital requirements can be easier met by households that have accumulated some wealth. However, there might be some sample bias in the sense that in many cases adopters were participants in a project and thus more respected farmers who are higher up in the village hierarchy and thus most likely of older age as compared to the average farmer might have been selected as participants. In a similar manner, the fact that male headed households are more likely to adopt new technologies such as aquaculture, might point to underlying differences in male and female headed households such as the availability of family labor or access to suitable land as pointed out for the case of agricultural innovations by Doss and Morris (2001). The other key adoption factors that were identified (Table 5) are access to resources such as suitable land, water and extension services and are well in line with the results of the literature review presented above. Most of the significant variables in the second analysis stage that focuses on the explanation of continued adoption (Table 6) are indicators of networks and social environment. Based on data set 4, farmers who were member of a fish farmers’ club or had contact with an extension officer or project staff were more likely to continue fish farming.

**Table 6:** Factors determining continued adoption of aquaculture production in Malawi

	Data set 4
Share of farm land with good quality soil	0.65 *
Member of fish farmers’ club	0.68 ***
Source of information – extension officer	0.90 ***
Source of fish farming information – project	0.86 **
Source of fingerlings (donation from neighbors)	1.21 ***
Source of fingerlings (purchase from neighbors)	1.30 ***
Source of fingerlings (purchase from other farmers)	1.70 ***
Source of fingerlings (purchase from DoF)	0.92 ***
Source of fingerlings (other sources)	2.18 ***
Regional dummy for Southern Region	0.62 *
<i>Log likelihood</i>	-106.88

Note: Dependent variable = 1if adopter, 0 if ex-adopter. \*, \*\*, \*\*\* stand for 0.1, 0.05, and 0.01 level of significance.



The results in Table 6 also highlight the importance of the availability of fingerlings. In the regression we used “own production of fingerlings” as the default and found that farmers are much more likely to continue fish farming, if there is an external source for fingerlings.

The situation is slightly different for the intensification of IAA practices that is defined as an increasing integration of aquaculture production into the overall farming system (measured as the ratio of number of bio-resource flows and number of enterprises on the farm). The IAA technologies especially pay off for farms with sufficient land for different farm enterprises (both crop and livestock production) and access to irrigation water that helps to realize higher crop yields (by-products are used as feed for fish) as well as perennial fish farming. Dey et al. (2006) provide a detailed discussion of the driving forces and impacts of IAA adoption and different integration levels into the farming system.

For the regression analysis for the data sets from Bangladesh, the dependent variable was a dummy for a specific level of production intensity. For the FFP data the definition of the production intensity was input based (see column headers in Table 7). Traditional production in this case is characterized by irregular stocking without feeding and fertilizing, while improved extensive production is defined as stocking with different species and irregular feeding and fertilizing. Semi-intensive production still relies on stocking of different species, but regular fertilizing and supplementary feeding (with local ingredients) as well as proper stocking ratio and disease control is practiced (we followed the definitions defined by DoF). The finding that factors such as the gender and age of the household head as well as the pond ownership are significant when moving from traditional to improved extensive, but not for intensification from improved extensive to semi-intensive can be interpreted in a way that only farmers with the necessary conditions intensify beyond traditional production. For the DSAP data set, the production intensity was defined in an output based manner. All observations with a yield level higher than the average sample yield plus ½ standard deviation were considered high intensity as compared to the rest of the sample (others). The coefficient for the total pond area was negative for the DSAP data set (i.e. smaller ponds would have higher yields), while for the FFP larger ponds would increase the probability of higher production intensity.

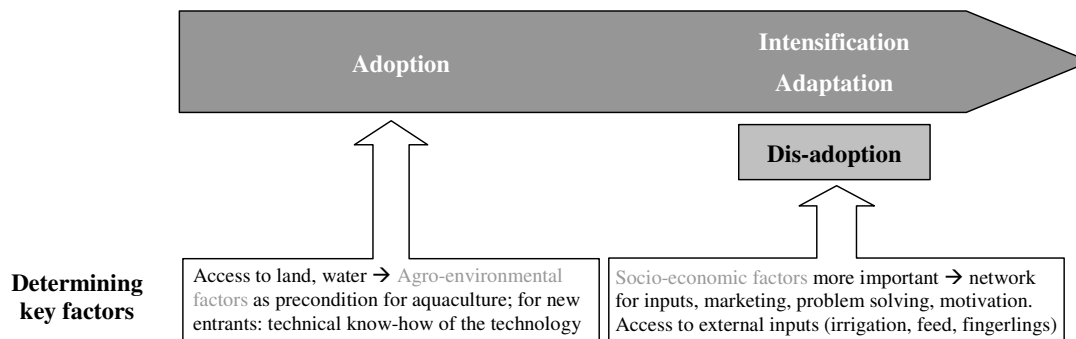
**Table 7:** Factors determining intensification of pond aquaculture in Bangladesh

	Data set 1	Data set 2	
	High intensity vs. others	Improved extensive vs. traditional	Semi-intensive vs. improved extensive
Exposure to full sunlight dummy	na	0.35 ***	0.54 *
Total pond area (ha)	-3.25***	2.63 ***	0.84 **
Soil type (dummy sandy loam)	na	0.24 **	0.43 **
Pond operation period (No. of months)	1.00***	0.05 **	0.198 ***
Gender of household head (1 for male)	0.59***	0.35 ***	0.10
Training from DoF (dummy)	na	0.83 ***	0.40 **
Age of household head (Years)	na	-0.01 **	< -0.01
Pond ownership (dummy, 1 for single)	na	0.51 ***	0.07
Experience in fish farming (Years)	0.03***	na	na
Education (No. of years)	-0.01	na	na
<i>Log likelihood</i>	<i>-561.76</i>	<i>-356.06</i>	<i>-151.18</i>

Note: Upward arrows stand for positive coefficients and \*, \*\*, \*\*\* are for 0.1, 0.05, 0.01 level of significance.

## OUTLOOK AND CONCLUSION

The data analysis of the first stage has shown that in Malawi and Bangladesh, the agro-ecological factors as well as the access to general inputs such as the availability of know-how, suitable land and sufficient capital are essential for the adoption of freshwater pond aquaculture. This result is in line with our expectations. When analyzing the dis-adoption of pond aquaculture in more detail, we found, that for a successful sustainable adoption (meeting farmers' expectations of generating income and providing an additional source of protein or food in general), socio-economic factors are more crucial. Based on the results we conclude, that farmers remain in business (i.e. continue or intensify production), when they are part of a network, i.e. they can observe and discuss fish farming practices with their neighbors, consult extension staff of either NGOs, projects, or the government, and have sufficient access to external inputs such as irrigation facilities, feed and fingerlings. Figure 3 schematically shows this shift in major driving forces (agro-ecological versus socio-economic factors) at different stages of aquaculture adoption. This result helps to better understand the respective driving forces of adoption/continued adoption and intensification/dis-adoption and subsequently can improve the targeting of (policy) interventions in a way that they are most effective. This could further be assisted by a matrix that on one axis shows the importance or magnitude of the constraint and on the other axis the costs of effort required to remove this constraint. Ideally, policy interventions would target on the very important and easy to change category.



**Figure 3:** Diagram depicting the adoption process and major influencing factors

Based on the findings of the micro-level adoption analysis as well as the literature review, we will in the next stage identify meso-level indicators that can be mapped. Examples for such indicators are the local wage rate as proxy for the opportunity cost of labor spent in fish farming, the availability of inputs (e.g. distance or travel time to closest hatchery or input provider) or major fish markets for selling of produce. The population density can be an indicator for both, the availability of labor as well as a proxy for local demand for produced fish. At the same time high population density might be correlated with scarcity of land and thus high opportunity costs for pond area. Equally, good infrastructure in an area can improve the availability of inputs such as fertilizer and seed and facilitate marketing of fish, but can also coincide with high education levels and thus alternative income earning options. As demonstrated by these few ad hoc examples, most indicators are not very meaningful when they are considered in isolation and their interpretation requires a solid understanding of the local system to prevent misleading conclusions. This stresses the importance of consulting experts and local stakeholders throughout the analysis process and a constant questioning of the results and assumed linkages.

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## ENDNOTES

- <sup>1</sup> The research presented in this paper is part of a project entitled "Determination of High-Potential Aquaculture Development Areas and Impact in Africa and Asia" that is coordinated by the WorldFish Center. The partner countries for the project are Bangladesh, Cameroon, China and Malawi. For more information please see the project webpage <http://www.worldfishcenter.org/rdproject/default.asp> or the project outline (Kam et al. 2005).
- <sup>2</sup> The authors are aware that this categorization makes extensive use of stereotypes and the aquaculture sector in the four countries is very diverse. This holds especially true for China, where a wide range of intensity levels of aquaculture production do coexist. However, this typology can be useful to extract lessons learned that can be applied for other countries.
- <sup>3</sup> Due to space limitations we do not provide the full result tables of the regression analysis but only significant variables. The results of the regression analysis of data set 3 (IAA) are published in Dey et al. (2006). For data set 4 (ADiM), some descriptive results are available from the project report (ADiM 2005) and the regression results are available on request from the authors. Results for the Bangladesh data are available on request.