Society and Natural Resources, 20:583–595

ISSN: 0894-1920 print/1521-0723 online
DOI: 10.1080/08941920601171824

Routledge
Taylor & Francis Group

Articles

Impacts of Extension Practice: Lessons From Small Farm-Based Aquaculture of Nile Tilapia in Northeastern Thailand

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This study compared the effectiveness of different extension techniques at communicating high-input inorganic fertilization (HIG) technology to small-scale, northeast Thai fish farmers. HIG adoption rates and associated fish production during 1997/1998 varied according to extension intensity across three farmer groups. Short training sessions were found to be equally effective at communicating HIG technology to farmers as longer on-farm trials. Both forms of extension were more effective than farmer-to-farmer communication at producing higher fish yields. Yields across all groups, however, were significantly lower than HIG-projected yields, suggesting that extension methodology did not exclusively affect production in this system. Farmer income, land holdings, attitudes, predisposition to risk, and fertilizer price all may have affected production. Improving production will involve a multifaceted approach, possibly including development of less capital-intense technologies, focus on short training sessions, encouragement of farmer cooperatives, and advocacy of economic policies that improve farmer access to credit and local markets.

Keywords aquaculture, extension, high-input inorganic fertilization, technology adoption, technology diffusion

Small-scale aquaculture is a significant source of local food security, employment, and income generation for some rural poor in developing nations (Edwards et al. 1996; ICAAE 1996; FAO 1997; Edwards 2000). Aquaculture is practiced extensively throughout many parts of the world, and freshwater aquaculture for fish, crustaceans, and mollusks totaled nearly 23 million tons and over US$26 billion globally in 2002 alone (FAO 2002). In 18 Asian and African countries, fish provide at least

Received 26 August 2005; accepted 8 October 2006.

Financial support for this project comes mainly from USAID Grant LAG-G-00-96-90015-00 through the Aquaculture Collaborative Research Support Program (CRSP). The Aquaculture CRSP accession number is 1317. The opinions expressed herein are those of the authors and do not necessarily reflect the views of USAID. Research could not have been done without the support of those at the Aquaculture Outreach Programme (AOP), Udorn Thani, Thailand. D. Turongruang, P. Suvannatrai, and the AOP staff generously provided field and technical support, as well as office and living space. The authors also thank Drs. H. Demaine, C. K. Lin and P. Edwards for providing insightful advice and valuable literature.

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40% of animal protein for human diets (Edwards 2000), and aquaculture produces about 35% of the annual fish harvest (Diana 2004).

Evidence suggests, however, that the great majority of people in the developing world still lack adequate food security. According to the United Nations Development Programme (UNDP) *2004 Human Development Report*, an estimated 831 million people in developing countries were undernourished in 2000, one quarter of whom live in the East Asia and Pacific region (UNDP 2004). According to UN Food and Agriculture Organization (FAO) estimates, the numbers of undernourished people living in Asia and the Pacific region are even higher than the UNDP reports (FAO 2004).

Significant effort has been devoted to research and development of new agricultural technology, and subsequent transfer of new technology to the farm-systems level (Hayami 1974; Molnar and Clonts 1983; Feder et al. 1985; Birkhaeuser et al. 1991; Rogers 1995). Aquaculture extension is essential for communicating technology to the farm level, where socioeconomic benefits of fish culture can be realized by individuals, families, and rural communities (ICAAE, 1996). Extension personnel are agents of change who liaise between research scientists and local communities, relaying technical information between the two (Rogers 1995). Using a variety of specialized tools and techniques, extension agents fill a vital role in the process of technology diffusion, as scientists do not generally have the time, resources, or skills required to directly promote application of their research findings to farmers.

High-input inorganic "green water" (HIG) technology is a prescription for small-scale aquaculture management and has been shown to result in fish production of over 4000 kg ha^{-1} yr^{-1} (640 kg rai^{-1} yr^{-1}) (AOP 1997). HIG fertilization produces "intense, green, plankton-rich water," and studies of HIG use in northeastern Thailand have demonstrated a 3:1 relationship between the monetary value of HIG-produced fish relative to estimated HIG-related production costs (Edwards et al. 2004a).

HIG recommendations for a 1-rai pond (1 rai = 1600 m^2) stocked with 3200–4800 sex-reversed Nile tilapia (*Oreochromis niloticus*) fingerlings are as follows: urea at a rate of 9.8 kg/week, and triple-super phosphate (TSP) at a rate of 5.6 kg/week. For extension purposes the Thai Department of Fisheries (DOF) and the Asian Institute of Technology's (AIT) Aquaculture Outreach Programme (AOP) simplified these recommendations to 10 kg urea/week and 5 kg TSP/week.

The first objective of this study was to determine whether 1997/1998 fish production varied in relationship to farmers' differing levels of exposure to a technology source. The "technology" was HIG recommendations; the "source" for these comparisons was the Thai DOF and AIT's AOP. Active extension agencies, DOF, and AOP are the primary conduits of aquaculture technology within northeastern Thailand. Some farmers receive routine training and contact with these organizations. Other farmers have no contact with DOF or AOP and receive information about aquaculture technology from neighboring farmers or relatives instead. A major focus of this study was to determine whether varying levels of extension (intense, moderate, and none) affected farmers' motivation to adopt technical recommendations, accuracy in following recommendations, and subsequent fish yield.

A second objective of this study was to identify significant factors other than extension affecting aquaculture management in northeast Thailand. Variation in exposure to extension education is unlikely to be the only external factor influencing fish pond management. The quality of the farmer-extensionist relationship, fertilizer price, local market conditions, and/or farmer predisposition to risk all potentially affect new technology adoption.

In order to achieve these objectives, 74 northeastern Thai fish farmers were surveyed about their experiences with aquaculture extension, their 1997/1998 fish production, and their views about various factors that affected their fish farming practices.

Methods

Trialists were farmers who had worked intensively with AOP/DOF on field-testing HIG technology. During on-farm trials, AOP or DOF staff visited farmers twice a month for 6 months. Trialists had the highest level of contact with extensionists and were hypothesized to have the highest fish yield for 1997/1998. Twenty-five farmers were randomly selected out of all those who had completed an HIG on-farm trial between 1995 and 1997.

Trainees were farmers who had at some point in the past received HIG recommendations via short-term training sessions from the DOF or AOP. As part of each organization's extension efforts, 1-to 2-day training sessions are given periodically to local farmers in order to train them in various aquaculture techniques. Participating farmers may be personally selected by extension workers, recommended to attend by people other than extensionists (such as village headmen), or sometimes may ask to attend personally (H. Demaine 1998 personal communication). Trainees had significantly less exposure to AOP/DOF than on-farm trialists, and were hypothesized to have lower levels of fish production for 1997/1998. Twenty-five trainees were chosen at random to be surveyed.

Traditional diffusion farmers are those who received HIG fertilization information from neighbors or relatives but who had no contact with extensionists. Traditional diffusion farmers are so titled because information diffuses spontaneously from a source like the DOF outward, at some point reaching the farmer. Technology most likely diffuses via word-of-mouth communication, and in many cases the intermediaries are trialist and/or trainee farmers, who relay technical information they have received from extensionists (Pant et al. 1998). Farmers were considered eligible for inclusion in this study if they satisfied two criteria: (1) They had current active engagement in fish farming, and (2) they had received HIG technology from sources other than the DOF or AOP. Because traditional diffusion farmers had no direct contact with extensionists, they were hypothesized to have the lowest 1997/1998 fish yields compared to trialists and trainees.

Potentially eligible names of traditional diffusion farmers were taken from surveys that AOP had conducted in previous years on trialists and trainees. A question included in past surveys was, "Would you recommend HIG technology to others? If you have already done so, who were they?" (Demaine 1998 personal communication). Based on responses to this question, more than 25 farmers were chosen at random from the names available, and the first 25 eligible farmers were included in the study.

Research was conducted in three northeastern Thailand provinces: Udorn Thani (Bandung and Tung Fon districts); Sakhon Nakhon (Pannanikom district); and Nakhon Phanom province (Nawa district). This study was tied to work being done at the AOP field station in Udorn Thani, which has worked closely since 1988 with the DOF and northeastern Thai communities on aquaculture issues including transfer of HIG fertilization technology (Edwards et al. 2004a). Small-scale aquaculture is practiced heavily in this area, with approximately 50% of all fish farms in the country located in the northeastern region (Edwards et al. 2004b). Fish is the major source of animal protein in the diet even among the poorest people in this region (Pant et al. 2004).

As the purpose of this study was to track the flow of HIG technology from extensionists to farmers, study sites were chosen from among areas where HIG extension was taking place. Provinces surveyed were physically and culturally comparable yet geographically disparate enough to be representative of the region. Farmers from each geographical area were included in each survey group.

Structured interviews were administered throughout June–July of 1998. AOP staff verbally administered surveys to all farmers in Thai. All interviews were conducted in farmers' homes and took approximately one hour to complete. AOP staff were chosen to administer farmer interviews due to their familiarity with the coverage area, their ability to speak the local language, and their ready access to transportation and other support infrastructure. This decision was weighed against the risk of AOP staff introducing bias into the interview process due to their role as extension agents.

Three separate surveys were designed, one for each farmer group, though some survey sections were identical for comparison purposes. Socioeconomic background questions focused on family size, available on-farm labor force, total annual cash income, and amounts and types of property held. Questions about farmers' aquaculture histories included number and size of ponds owned; years of aquaculture experience; past and current fish production levels; and management levels (feeding, fertilizing, and fish stocking) pre- and post-HIG awareness.

Trialists were asked their reasons for fish farming; perceptions about the value of aquaculture activity; attitudes toward the DOF; reasons for participating in on-farm trials; and preferred sources of additional technical assistance. Trainees were asked about their motivations for fish farming; motivations in attending aquaculture training; perceptions about the usefulness of training sessions attended; whether they had sufficient contact with the DOF or AOP; and preferred sources of additional technical assistance. Traditional diffusion farmers were asked how they had heard about HIG; whether their information source was accurate and trustworthy; whether they were able to use HIG information; whether they planned to continue aquaculture activities in the future; and if so, how they planned to improve their management skills. All farmers were asked to list problems they experienced with fish farming and to rank problems in order of severity.

Statistical analyses were done using SYSTAT 7.0 (SYSTAT 1990). All analyses were performed at the $\alpha = .05$ level of significance. Residual analyses were performed for all tests where results were significant. Normality of residuals was tested using a combination of Lilliefor's and skewness and kurtosis tests, and homogeneity of variance using Levene's test.

Analyses of variance (ANOVAs) were used to assess socioeconomic uniformity between groups of farmers. Parameters tested included mean farmer age, family size, amount of land owned, income, area of fish ponds owned, and years of aquaculture experience. A one-way ANOVA was used to detect variation in mean 1997/1998 fish production between trialist, trainee, and traditional diffusion groups. Significant differences between group means were followed up using Tukey's HSD multiple comparisons tests. Paired *t*-tests were run to compare mean fish production of trialist, trainee, and traditional diffusion groups with known HIG yield projections.

Table 1. Socioeconomic characteristics of each surveyed farmer group, and results of one-way ANOVAs comparing variables among groups

	Group			
Socioeconomic variable	On-farm trialists	Trainees	Organic spread	*p* value
1997/1998 Income (Thai Bhat)	56,997	53,072	73,605	0.28
Age (years)	48.2	49.0	49.1	0.96
Number of farm laborers available	3.0	2.9	2.8	0.92
Number of family members	5.8	5.5	5.0	0.30
Total land owned (rai)	28.2	31.5	28.6	0.88
Total land actively farmed (rai)	22.2	22.9	21.3	0.91
Total pond area (m^2)	1303	1109	1792	0.34
Number of ponds owned	1.7	1.4	1.6	0.73
Years of aquaculture experience	5.5	5.2	4.4	0.30

Note. All values except *p* values represent group averages per farmer. At time of survey, US$1 $\approx$ 40 Thai Bhat.

A combination of stepwise regression and multiple linear regression techniques was used to detect relationships between socioeconomic variables (family size, income, etc.) and fish production. Analyses were run both within groups and over the entire sample group (all farmers together). In order to avoid multicollinearity, Pearson's correlation matrices, in conjunction with stepwise regression techniques, were used to eliminate some socioeconomic variables from final regression models. Thus, for example, number of ponds owned was not included in a model with total pond area available for aquaculture.

Results

The final sample size for this study was 74 farmers, due to the death of one trialist who was initially selected as part of the sample. There were no significant differences among the three study groups in major socioeconomic variables (Table 1). No significant differences existed between mean income, age, number of laborers available, family size, amount of land owned, amount of land actively farmed, years of aquaculture experience, number of ponds, or size of ponds between the three groups.

Although some farmers strictly used HIG technology, most utilized a variety of other management techniques, either in conjunction with or instead of HIG. Rather than solely using urea, TSP, and sex-reversed tilapia, most farmers used an assortment of fertilizers (urea, TSP, pig/chicken/ruminant manure, rice), feeds (pellet feed, rice bran, termites, vegetation), and fish species (tilapia, catfish, silver barb, common carp, Indian major carps).

There were significant differences among study groups in fish yield achieved on their farms ($p = .007$). Fish yield included production of all fish species present in farmers' ponds, not solely tilapia. To standardize for high levels of variation in pond area cultivated, fish yield was measured as absolute fish production (kg) per hectare. Log transformation of production was used in order to meet equal variance and

Table 2. Results of regression analyses of socioeconomic variables affecting total fish production

Variable	Coefficient	Standard coefficient	*p* value
Trialists (*p* value $<.0000005$, $r^2 = .784$)			
Total income	0.002	0.338	.041
Total land owned	6.668	0.611	.001
Trainees (*p* value $<.0000005$, $r^2 = .730$)			
Total income	0.001	0.375	.009
Total pond area	0.075	0.583	.0002
Organic spread (*p* value $= .000011$, $r^2 = .646$)			
Total income	0.001	0.361	.025
Total pond area	0.081	0.550	.001
All farmers (*p* value $<.0000005$, $r^2 = .652$)			
Total income	0.002	0.391	.00005
Total pond area	0.085	0.506	<.00005

normality assumptions. While mean fish production of trialists (2648 kg/ha) and trainees (2480 kg/ha) did not differ significantly from each other ($p = .969$), mean production of the traditional diffusion group (1581 kg/ha) was significantly lower than for the other groups ($p < .05$). Though trialists and trainees out-produced traditional diffusion farmers, no group produced at a level close to HIG projections. Projected HIG yield was significantly higher than trialist ($p = .007$), trainee ($p = .025$), and traditional diffusion farmer ($p < .000005$) production.

Factors affecting fish production included total farmer income (from fish and other sources) and a spatial variable (land owned or pond holdings) within and across all farmer groups (Table 2). Only one spatial variable (land or ponds owned but not both) was included in each group's regression model, as these variables are correlated. In the case of trialists, total land owned was significantly related to fish production; pond area was significantly associated with production for the other groups.

Fifty-four percent of trialists, 16% of trainees, and 28% of traditional diffusion farmers stated they had followed HIG-use recommendations in 1997/1998. Of the three groups, traditional diffusion farmers claimed to devote the most time per day to aquaculture (29 min/day) compared to other groups (20 min/day). Thirty-four percent of all farmers stated that time spent on fish farming was allocated only after all other farm duties were completed, and that the only activity performed was fish feeding (not fertilizing or maintaining ponds).

The primary motivation for fish production among study farmers was private consumption, although 40% of farmers said they also raised fish to sell in local markets (not for commercial export). No farmers raised fish solely for sale. An average of 84% of all farmers perceived local market conditions as good, with high village consumption leading to high opportunity to sell surplus fish. Farmers stated that the only significant sources of competition were other merchants or fish caught from public water bodies, but that neither of these negatively affected their ability to participate in the market. As a result, fish farming was profitable for some. On average, 40% of those who marketed fish in 1998/1999 increased their incomes by 15%.

Fifty-eight percent of trialists reported that desire for self-verification of HIG efficacy or for additional aquaculture improvement techniques prompted them to participate in on-farm trials. These trialists expressed dissatisfaction with prior aquaculture attempts and were motivated to take steps to increase production. Trainees also showed substantial interest and initiative. When asked how they had heard about HIG training, 84% reported that they had personally sought information from village headmen and volunteered attendance. It is difficult to comment on traditional diffusion farmer motivation and attitudes, as it is unclear whether they received HIG information actively or passively.

Farmer opinion of the DOF was generally positive. Seventy-two percent of traditional diffusion farmers and 60% of trainees desired increased contact with DOF or AOP in the future, in order to improve management skills. When asked whom farmers went to when they needed assistance, 58% of trialists, 36% of trainees, and 33% of traditional diffusion farmers said they went to DOF because "their knowledge was the best," interpreted here as the most accurate. Decreasing relative percentages may reflect the level of familiarity with DOF, although other factors (like proximity to a DOF office) might influence farmer behavior. Forty-two percent of traditional diffusion farmers, for example, stated they sought information from neighbors because they were close by. Seventy-five percent of trialists and 44% of trainees considered DOF extensionists to be helpful, either because they made follow-up visits and offered advice, helped farmers solve problems, or answered questions freely.

Sixty-eight percent of traditional diffusion farmers described their HIG information sources as accurate, yet 56% also said the HIG information they received was "insufficient." These farmers described the information received as being too unclear to follow.

Discussion

This study's results should be interpreted with the following qualifications and assumptions in mind. Though care was taken to survey a random portion of the northeastern Thai fish farming population, some sampling error was unavoidable. Trialists included in this study may not be truly representative of the entire culturist population. In this study, trialists were chosen randomly from all past on-farm trialists. The original trialists, however, may not have been representative of the general population, as one of AOP's stated goals is to "recruit the poorest farmers" for participation in trials (AOP 1990). The magnitude of this error was probably minimal, however, as socioeconomic analyses showed farmers across groups to be financially similar. In addition, if trialist farmers were poorer than trainee or traditional diffusion farmers, one might expect their production to be the lowest, not the highest.

The methodology used in sampling traditional diffusion farmers may also have introduced error. Traditional diffusion farmers were identified for inclusion in this study by trialists and trainee farmers; the traditional diffusion farmer sample was therefore not a random sample of the broader traditional diffusion farmer population, and indeed traditional diffusion farmers' 1997/1998 income was the highest of the three farmer groups (though not significantly higher). It is possible that trialists and trainees identified relatively successful traditional diffusion farmers, and/or avoided identifying traditional diffusion farmers who pursued little or no fish-farming activity. If this was the case, the bias would likely be toward overestimating traditional diffusion farmer fish production. However, overestimating productivity of traditional diffusion farmers would strengthen the findings of this study, that is, that traditional diffusion farmer yield was significantly lower than trialist and trainee farmer yields.

Two major assumptions were made in conducting this study. HIG fertilization was assumed to be a truly effective method of improving tilapia yield in northeastern Thailand. Whether HIG is appropriate or useful under all local conditions is uncertain. Much research has concluded, however, that HIG is in fact effective for increasing tilapia production in rural, small-scale aquaculture ponds (AOP 1997; FAO 1997; Edwards et al. 2004a; Pant et al. 2004).

It was also assumed that survey respondents gave honest, complete answers to interview questions. Research has shown that many factors can influence degree of accuracy of interviewee responses. Interviewee mood, ulterior motives, desire to please interviewers, or inability to recall information could all lead to response distortion (Whyte 1982). In addition, response error could be introduced by the interviewers themselves (in this case AOP staff), via their inexperience, inaccuracy in recording data, or expectations of a certain response (Moser and Kalton 1972). AOP-based interviewers may have influenced interviewee responses related to opinions about AOP/DOF staff, services, and trainings, and/or about respondents' farm productivity. It is possible that farmers felt inclined to share positive rather than negative opinions with interviewers, or to overestimate fish yields. Potential bias, however, likely affected all farmers consistently. In addition, potentially overestimated fish production would further strengthen this study's findings that all groups' yields were lower than projected HIG yield.

Given the above qualifications, this study's data indicate wide variation in the rate of HIG adoption between farmer groups. Fifty-four percent of trialists reported using HIG technology at some point in the previous growing season, compared to only 16% of trainees, and 28% of traditional diffusion farmers. Of those farmers who reported using HIG, most did not report fertilizing with urea and TSP according to exact DOF/AOP recommendations, but rather combined HIG guidelines with other fertilization, feeding, and fish stocking regimes. Few farmers reported applying recommended amounts of urea and TSP to their ponds, and even fewer reported applying recommended amounts for the entire grow-out period.

Many farmers reported supplementing or substituting HIG with other inputs (manure, feed, etc.). Deviation from HIG recommendations may explain why all groups' fish production levels were considerably lower than projected HIG levels. Clearly, factors other than extension method influenced HIG adoption among farmers surveyed. This study's results indicate that a variety of external factors may decrease farmer willingness to invest in not only HIG, but perhaps any semi-intensive aquaculture management technology. Among these external factors may be farmer attitudes toward development, technology cost-effectiveness, local market constraints, or farmer ability to assume risk. Problems within development ideology, extension methodology, and the diffusion of innovations model may also affect farmers' tendency to adopt HIG.

On-farm trials were not the most efficient method of HIG technology extension available to the Thai DOF compared to short training sessions. Although more trialists reported following HIG recommendations within the previous year than other farmer types, and trialists did experience higher rates of tilapia production, trialists did not produce significantly more than trainees did, indicating that 1-or 2-day group training sessions were at least as effective as 6-month trials for transmitting useful HIG technology to farmers. From an implementation perspective, short training sessions may be better uses of resources than on-farm trials.

These results also indicate that at least some contact with extension agencies was beneficial for increasing fish production, as trialists and trainees had significantly higher production levels than traditional diffusion farmers. Traditional diffusion farmers had significantly lower yields, even though they reported using HIG technology more than trainee farmers, and spending more time per day on aquaculture activities than other farmer types. This higher effort:yield ratio suggests that farmer-to-farmer communication was not as effective as extensionist-to-farmer communication at transferring HIG technology.

One reason for this is that information-sharing or "source" farmers may not possess (or share) technically accurate or complete information. Although source farmers may receive HIG technology directly from DOF or AOP, individual memory and interpretation may alter information passed on to other farmers. Unless source farmers share printed extension materials (pamphlets, posters, etc.), it is likely that specific details regarding fertilization rates and fish stocking densities may be distorted, confused, or forgotten. Over half of the traditional diffusion farmers stated that their sources were knowledgeable but that their advice was generally incomplete. Thus, even accurate information received may have been insufficient for action. In a study of farmer-to-farmer communication in a Brazilian village, Schneider similarly found that "information reported by the respondents drops considerably and consistently for all messages at the interpersonal level of communication" (Schneider 1974). Schneider concluded that, when transferring agricultural technology, "people do not pass along all the information they receive."

Lack of communication skills may also limit effectiveness of farmer-to-farmer communication. Possessing accurate information does not mean possessing teaching or communication skills. Extensionists are trained to transfer technical information to target audiences, and often have tools or educational aids for demonstration purposes. The probability of this being true of trialist or trainee farmers is low. Furthermore, Feliciano (1974) found that farmers were often reluctant to be agricultural "information-givers," due either to (1) fear of recommending potentially risky technology to peers; (2) skepticism of the technology itself; (3) lack of motivation to share information; or (4) desire to keep innovation for themselves. All of these factors may have influenced the rate and quality of information diffused via passive communication channels.

Of all socioeconomic variables tested, only total farmer income and land or pond holdings were significantly related to fish production. Greater production capacity was dependent upon bigger ponds and larger amounts of capital investment, but not upon farmer age, family size, number of laborers available for work, or years of aquaculture experience. This finding is consistent with other adoption studies among subsistence farmers in developing country contexts, where positive relationships have been found between farmer access to land, capital, or both and increased technology adoption (Feder et al. 1985; Karki and Bauer 2004). It is surprising that the available labor force did not have an impact on fish production.

Since farmers stated that time was allotted to fish farming only after all other chores were completed, increased labor availability would seemingly allow farmers more time to actively manage their ponds.

Certain farmer attitudes facilitate development and change, with farmers adopting and retaining technology largely according to personal choice. According to Mosher (1960), attitudes that facilitate agricultural development include: (1) dissatisfaction with present levels of production or consumption; (2) confidence that increased production is possible; (3) willingness to experiment, even in the face of possible failure; (4) confidence in agents of change; (5) a sense of personal responsibility; and (6) readiness to make independent decisions regarding the future. Farmers possessing these attitudes are likely to be early adopters of innovation (Rogers 1995). Many trialist and trainee farmers in this study did appear to possess early adopter characteristics, such as high degrees of curiosity, initiative, and self-motivation to try HIG.

Farmer-extensionist relationships that are mutually respectful and participatory in nature are essential for fostering smooth technology diffusion (Edwards 2000). Distrustful, skeptical, or disdainful attitudes between farmers and extensionists/extension agencies would seriously impair extensionists' ability to transfer technology successfully. Positive farmer-extensionist relationships likely facilitated aquaculture production in this system. Farmers generally felt extensionists to be knowledgeable, friendly, and helpful, and stated a desire for increased contact with DOF or AOP in order to further their own management skills. Strong relationships paired with high farmer motivation, however, were not enough to overcome other external factors that possibly inhibited larger fish yields.

One such factor was the cost-effectiveness of HIG fertilization, which in the early 1990s was estimated to cost about 4000 Thai Bhat/rai, making it a highly cost effective alternative to farm-based organic fertilization (AOP, 1997). Cost estimates were based on an initial stocking of 3000 tilapia and a 6-month allotment of urea and TSP. In this study, a 4000-Bhat initial investment represented 5.5–7.5% of farmer income/rai. Given fish production projections of 600–640 kg/rai in a 6-month culture period and a market price for fish of 30 Bhat/kg, estimated gross profit was 18,000–19,200 Bhat/rai, resulting in a projected net profit of 14,000–15,200 Bhat/rai (AOP 1997; Pant et al. 1998).

However, the financial situation changed drastically in 1998, as, almost simultaneously, inorganic fertilizer prices increased significantly and the Thai economy plummeted during an Asian economic crisis. At the time of the original cost projections, TSP cost 8 Bhat/kg, and urea cost 5 Bhat/kg (AOP 1997). By 1998, however, the TSP price had increased to 13 Bhat/kg, and urea to 9 Bhat/kg. Given these higher prices, initial cost projections changed from 4000 Bhat/rai to 5580 Bhat/rai, representing an increase in initial capital investment to 7.7–10.7%. Concurrently the Thai Bhat was significantly devalued, with US$1 = 40 Bhat at the time of this study, compared to US$1 = 25 Bhat in 1997.

It is difficult to separate the impacts that the currency devaluation and fertilizer price increase had on farmers' ability to adopt HIG technology, as both conditions in tandem likely inhibited inorganic fertilizer use in 1998. Of trialists experiencing aquaculture problems in 1996, only 16.7% stated these were cost related. By 1998, 38.5% of trialists reporting difficulties said that high cost (of HIG, fish farming in general, or both) limited increased aquaculture management. Twenty-eight percent of traditional diffusion farmers and 26% of training farmers reported they were not willing or able to use HIG due to high fertilizer cost.

In terms of local market conditions, survey results indicated that (1) farmers raised fish for private consumption and local sale but not for export purposes, (2) farmers perceived local market conditions as good, and (3) selling surplus yield was profitable for some farmers. Given these results, it is reasonable to ask why more farmers surveyed did not participate in the local commercial fish market.

Farmer ability to sell surplus production depends greatly on the extent of existing market infrastructure, as well as consumer purchasing capacity (FAO 1997). Markets constrain growth in agricultural systems when producer supply and consumer demands are unequal or mismatched, or when prices for inputs or outputs are not commensurate with their true value (Hayami and Ruttan 1985; Sankar and Mythili 1991). Within the context of this study, the absence of many commercial farmers was likely due to a combination of farmer disinterest in selling surplus and a limited volume of surplus fish. In this case, it is fairly unlikely that external market constraints (such as low demand or high competition) restricted farmer access to the market, as several studies have assessed farmer access to local markets in this region as good (Edwards et al. 2004b; Pant et al. 2004). If adoption of HIG fertilization resulted in a majority of farmers experiencing significantly improved fish production, however, market constraints could become important. Dramatically increased supply unmet by increased consumer demand would eventually discourage farmers from improving management efficiency.

Given the largely subsistence rather than commercial nature of the farmers in this study, it is perhaps unsurprising that farmer motivation and ability to adhere strictly to HIG recommendations were low. It is possible that HIG adoption rates and fish yields might have increased significantly across some or all groups if farmers raised fish for commercial rather than personal consumption purposes. Among study farmers, motivation to participate in extension activities may have been dampened by farmers' subsistence rather than commercial orientation. Farmers' ability to improve management practices may have been constrained, for example, by competition between limited farm versus household labor, land, and capital (Phuphak 1993; Karki and Bauer 2004).

Regarding farmer risk and uncertainty, new technology is unusual in that it simultaneously creates and reduces uncertainty for people (Rogers 1995). Here, HIG technology promises higher tilapia production, thereby reducing risks of aquaculture investment. Yet fear of potentially risky investment creates uncertainty for farmers (especially poor farmers) considering HIG adoption. Risk aversion is prevalent in rural farmers, as financial risks tend to be large relative to available income (Sankar and Mythili 1991; Lewis 1997). Subsistence farmers generally invest less in new technology and accept lower resource returns in return for enhanced certainty of future returns (Roe 1983; Lewis 1997; Karki and Bauer 2004).

Risk aversion therefore may be a factor inhibiting widespread HIG adoption among farmers in this study, despite the fact that fish farming did generate income for approximately 40% of the farmers sampled. Avoidance of technological or financial uncertainty may help explain why 47% of all farmers surveyed said they would not improve their aquaculture operations in 1998/9. Major reasons stated were lack of expendable investment capital, lack of labor resources, and overall lack of motivation to extend themselves further. These same factors have been found to constrain agricultural technology adoption in other developing country contexts as well (Feder et al. 1985; Phuphak 1993).

Conclusion

In conclusion, improving fish production among northeastern Thai farmers will require more than improvements to the aquaculture extension process. From an economic perspective, if inorganic fertilizer costs remain prohibitive, research should focus on finding cheaper, more cost-effective alternatives to HIG fertilization. From an extension agency's perspective, it would be prudent to dedicate training resources to 1- or 2-day sessions, rather than to extensive on-farm trials. From a social or community perspective, farmers could be encouraged to form small-scale aquaculture cooperatives in order to compensate for individual lack of sufficient working capital and/or land holdings. Since farmer income and land/pond holdings were the only factors found to be related to fish production in this system, strategies to pool farmers' resources could be developed in an attempt to create more advantageous economies of scale. Finally, from a government perspective, attention should be paid to price structures, conditions of local markets, and farmer access to credit. As even small-scale aquaculturists work within a wider economic system, prices of aquaculture inputs and outputs and ability to access credit will affect farmers' management decisions.

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