Analyzing Spatial and Temporal Changes of Aquaculture in Yunlin County, Taiwan*

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This article analyzes spatial and temporal changes of aquaculture land use in Yunlin County, Taiwan, and discusses the driving forces for these changes. Digital land-use maps and satellite imagery for 1982, 1988, 1994, and 2002 were used to extract aquaculture areas. A geographic information system was used to derive changes in aquaculture areas and to compute the spatial clustering statistics over time. A survey of eighty-seven farmers was conducted to obtain their views and concerns about aquaculture. The results show a rapid expansion in aquaculture during the 1980s, driven mainly by exports to Japan, and a continuous decline since the mid-1990s because of economic, environmental, and demographic factors. **Key Words: aquaculture, GIS, questionnaire survey, spatial analysis, Taiwan.**

Aquaculture has had a long history along the west coast of Taiwan. Historical records show that milkfish culture, carp polyculture, and poultry-integrated aquaculture systems existed on the island's southwestern coast more than 300 years ago. Aquaculture gradually evolved from a temporary to a stable land-use type, and in the 1960s aquaculture became a viable food production activity. As incomes rose in the 1970s, aquaculture farmers raised shrimp, clam, tilapia, and other species, in addition to milkfish and carp, to meet consumer demands in Taiwan. The opening in Japan of export markets for eel and shrimp provided an impetus for further expansion in the 1980s. Taiwan became the major source of shrimp and eel imports in Japan during the 1980s (Traesupap, Matsuda, and Shima 1999; Lee et al. 2003). The total production of aquaculture increased from 54,800 metric tons in 1970, to 145,000 in 1980 and 275,900 in 1987. But in 1987 Taiwan's aquaculture suffered a major setback as an onslaught of virulent diseases nearly wiped out the island's shrimp industry (Lin 1989). The production of black tiger shrimp fell from 80,000 metric tons in 1987 to 20,000 in 1988.

Ecosystem mismanagement such as larval rearing conditions and water pollution was blamed for the viral diseases (Lin 1989). But the collapse of shrimp culture also exposed environmental problems generally associated with aquaculture. The emptying of groundwater for aquaculture use had led to intrusion of seawater and land subsidence (Chen 1990). Aquaculture was also linked to coastal plain erosion, water pollution, salinization of soils, and abandoned fishponds. At the same time, competition from Thailand, China, and other Asian countries had cut into Taiwan's aquaculture exports. Although the problem of disease affected only shrimp, just one of more than a hundred cultured species in Taiwan, its impact nonetheless set off a gradual decline of Taiwan's aquaculture.

Aquaculture has been largely overlooked in the land-use change literature. This is surprising given that aquaculture, especially shrimp farming, has been an important source for exports in countries such as Taiwan since the 1980s and more recently in Thailand, Ecuador, China, and Peru (Rosenberry 1998). Moreover, aquaculture is directly related to current research interests on global land-use change (Matson et al. 1997; Lambin, Rounsevell, and Geist 2000) and to environmental and sustainability issues (Tisdell 1999). Perhaps this neglect of aquaculture is due to the difficulty of obtaining adequate locational and temporal data. Because many family-owned fishponds in

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Asia are smaller than 1 hectare (ha) in size (Kongkeo 1997), they are often left out of land-use maps, nor can they be easily delineated on coarse-resolution satellite images.

This study is designed to fill a gap in the land-use literature by analyzing the spatial and temporal changes of aquaculture in Yunlin County, Taiwan. This research can improve our understanding of land-use changes and their driving forces in a local context. Researchers in land-use changes have long recognized the importance of local studies in complementing analyses at the regional and global scales (Gallopin 1991; Meyer and Turner 1994). This study can also assist future studies of aquaculture and other intensive land uses in dealing with the data and methodological issues.

Methods

Study Area

Measuring 30,210 ha in size, the study area consists of four coastal townships (Mailiao, Taisi, Sihhu, Kohu) of Yunlin County in Taiwan (Figure 1). With a long history of fish farming, this area is part of the core region of Taiwan's aquaculture along the island's southwestern coast. Aquaculture within the study area has been concentrated in the north (Taisi and part of Mailiao) and the south (Kohu). The middle area (Sihhu) has two small harbors and shelterbelts near the coast; both physical features tend to interfere with commercial aquaculture. The shelterbelts also provide the option of growing agricultural crops in the protected areas.

Clam farming started in the north on the sandy beaches. In the 1960s, government-sponsored land reclamation programs created a large area of tidal flatlands. These tidal flatlands were too exposed to wind and salt water to allow economic cultivation of agricultural crops but were suitable for large-scale clam farming (Richards 1986). Clam has been the dominant species in the north, although tilapia and other species have also been raised for their economic values.

Aquaculture in the south started in poorly drained lowlands. Aquaculture farmers turned first to milkfish culture and later to eel production (Richards 1986). The opening of the eel market in Japan during the 1980s promoted the expansion of eel farming, both at the coast and at many inland locations. Salt water was brought inland by pipes; this was possible because eel farming requires less salt water than, for example, shrimp farming.

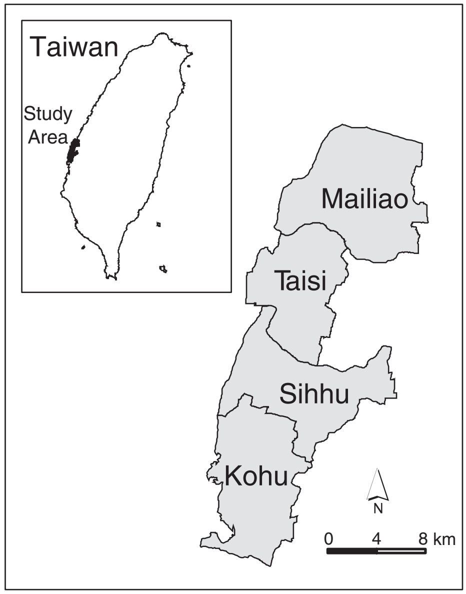

Figure 1 *The study area.*

Data

The Taiwan Fisheries Bureau publishes yearly statistics on aquaculture production and area but only at the county level. Aggregate county-level data are too coarse for spatial analysis of aquaculture. For this study, aquaculture areas for 1982, 1988, and 1994 were extracted from 1:5,000-scale digital land-use maps using a geographic information system (GIS). The 1982 and 1988 land-use maps were digitized by a government agency from air photos and were checked by field survey; the 1994 map was produced by a government agency from field survey. Aquaculture areas for 2002 were extracted from ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) imagery with a spatial resolution of 15 m in the visible and near infrared range. The extracted aquaculture areas were then vectorized to be consistent with the other three data sets. Figure 2 shows aquaculture areas in 1982, 1988, 1994, and 2002.

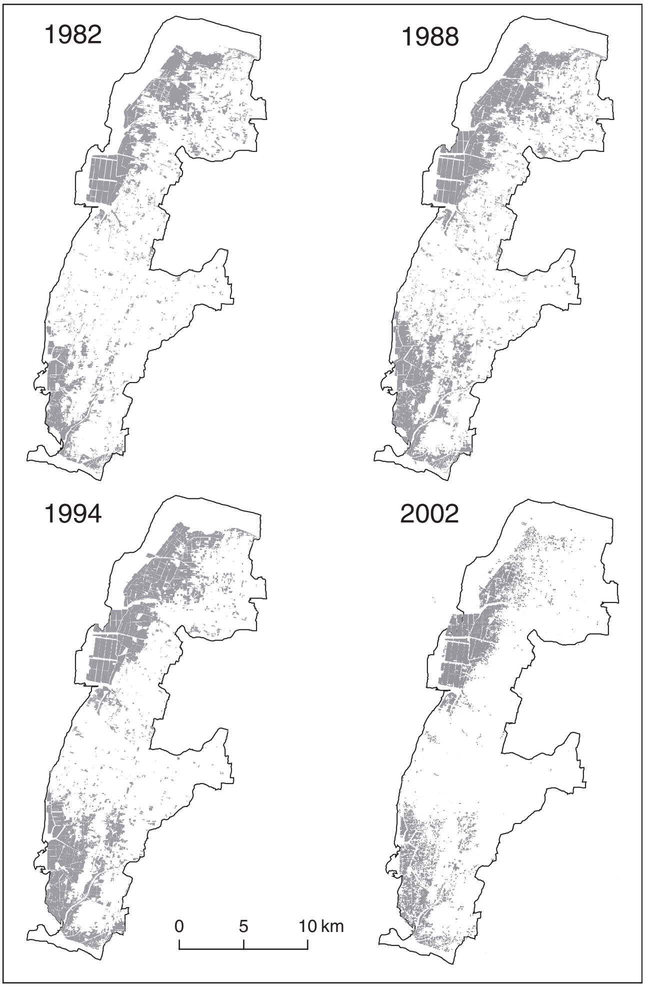

Figure 2 *Aquaculture areas in 1982, 1988, 1994, and 2002.*

Overlay Analysis

We used overlay analysis in a GIS to derive increases and decreases of aquaculture areas between years. Given polygon layers representing two different years (e.g., 1982 and 1988), the symmetrical difference method created an output layer showing aquaculture areas that were common to only one of the input layers (Chang 2004). We then separated areas representing increases from areas representing decreases by querying the attributes of the overlay output. For example, if a polygon on the overlay output between the 1982 and 1988 layers showed aquaculture in 1988, then it represented an area of increase from 1982.

A common problem with overlay analysis in a GIS is slivers, very small polygons along shared boundary lines of the input layers. Slivers are often caused by digitizing errors but can also be caused by erroneous interpretations from field survey data or satellite images (Chang 2004). Because this study used data from different years and different sources, slivers were unavoidable. We considered removing slivers by forcing polygon boundaries to be coincident prior to overlay operations, but that option required ranking the data sets in terms of their locational accuracy, which was impossible in our case. Instead, we reduced the amounts of slivers on the overlay output by using the following query expression: (area > 1 ha) or [(area > 0.5 ha) and (perimeter $<$ 300 m)]. This query expression preserved polygons that were larger than 1 ha regardless of their shape, and eliminated polygons that were either smaller then 0.5 ha or had perimeters longer than 300 m. A small polygon (i.e., $<$ 1 ha) with a long perimeter (i.e., $>$ 300 m) was typically made of a string of slivers on the overlay output.

Spatial Statistics

We used the local G-statistic (Getis and Ord 1992) to measure the spatial clustering of aquaculture areas for each layer in the GIS database. Usually based on a distance band, the local G-statistic can determine if there is a spatial clustering within the distance band of a point or the centroid of a polygon and if the clustering is made of high values or low values. A *Z* score can also be computed for a local G-statistic to determine its statistical significance. For example, a clustering of *Z* scores higher than 1.97 indicates the presence of a spatial clustering of high values. The local G-statistic is commonly used for crime mapping and analysis, although it has also been applied to studies of SIDS (Sudden Infant Death Syndrome), AIDs, and housing prices (Getis and Ord 1992, 1998). In this study, the local G-statistic provides a quantitative measure of the spatial pattern of aquaculture areas.

Given the aquaculture data such as those shown in Figure 2, we had two options for computing the local G-statistic. The first option was to use the data directly and let the GIS package (ArcGIS 9.0 for this study) derive a centroid for each polygon as inputs to local G-statistic analysis. The second option was to aggregate aquaculture areas by cell and to use the cells and cell centers as inputs. After experimenting with both options, we decided to use the second. Aquaculture areas tend to be connected with each other in forming odd shapes. The centroid for an odd-shaped polygon cannot represent the polygon well and can distort the result of spatial pattern analysis.

We made a grid with a cell size of 500 m, and overlaid the grid on the study area to aggregate aquaculture areas for each cell. The grid had a total of 1,366 cells, each 250,000 m^2 (25 ha) in area. If a cell had 50,000 m^2 in aquaculture, for example, the cell was recorded with a value of 50,000. We used the grid, which was actually a polygon layer with square cells, as the input layer, the aggregated values in each cell as the attribute values, and a distance band of 2,000 m to compute the local G-statistic.

Questionnaire Survey

Both GIS analysis and the local G-statistic are designed for analyzing the spatial pattern of aquaculture over time. But they cannot explain the driving forces that result in the pattern. In an earlier study, we used logistic regression analysis to predict the presence of aquaculture and found proximity to coastline and proximity to a major road to be statistically significant (Tsai et al. 2002). But the model only covers the relationship between the locations of aquaculture farms and the local physical variables. A fuller explanation, especially from the socioeconomic perspectives, can only come from the farmers (agents) who are, or have been, engaged in aquaculture operations (Shucksmith 1993; Schulman, Zimmerm, and Danaher 1994; Fox et al. 2003).

To gain a better understanding of aquaculture from the farmer's perspective, we conducted a questionnaire survey in September and October of 2004. Surveys are a common tool for gathering information in social sciences. According to Weisberg, Krosnick, and Bowen (1996), surveys can be used to measure things such as attitudes, beliefs including predictions and assessments of importance, and facts including past behavioral experiences. We used a stratified sampling method and a target sample size of 100 to derive a number of persons for each township that was proportional to the size of the aquaculture area within the township. We then randomly selected aquaculture farmers from each township for the survey. In the field, we were able to conduct the survey with 87 of the intended 100 farmers.

The questionnaire had twenty-three fixed-choice questions and four open-ended questions, grouped into three general categories: (1) background information on the farmer such as age, education level, farming experience, and size and location of his aquaculture operation; (2) environmental factors such as water supply, water quality, fish diseases, land subsidence, typhoon, and a newly built industrial complex nearby that might impact aquaculture operation locally; and (3) economic aspects of aquaculture farming as well as of external factors such as market prices and government policies that might influence the farmer's decision-making process.

Analysis of survey data consisted of three parts. First, we tabulated the responses to each survey question and derived the percentages of responses by choice or answer. Second, we constructed contingency tables between variables in the survey and ran chi-square tests for each pair of cross-tabulated variables to find statistically significant associations. Third, we ran a stepwise logistic regression analysis (Hosmer and Lemeshow 1989; Menard 1995; Bentz and Merunka 2000) with the questionnaire responses to identify predictive variables for the abandonment of aquaculture operations during the past ten years.

Results

Overlay Analysis

Table 1 shows aquaculture areas in 1982, 1988, 1994, and 2002. The increase in aquaculture areas from 1982 to 1988 was 33 percent, and the decrease from 1994 to 2002 was 46 percent. Aquaculture was relatively stable in terms of production area between 1988 and 1994. Figure 3 shows areas of increase from 1982 to 1988. In the north, the expansion tended to be adjacent to existing aquaculture areas. In the south, the expansion appeared in areas near the coast as well as inland. Figure 4 shows areas of decrease from 1994 to 2002. Except for a large aggregate of fishponds in the north, the disappearance of aquaculture occurred in nearly every part of the production areas in 1994.

Local G-Statistic

Figure 5 shows the *Z* scores of the local G-statistics that are higher than 1.97 for 1988 and 2002: The golden years of aquaculture in the study area are represented by 1988; the latest condition after years of decline is represented by 2002. The spatial clusters of high-value cells become smaller from 1988 to 2002 in both the north and the south. The contraction takes place mainly at inland locations. Also shown in Figure 5 is the intensification of aquaculture along the coast in 2002, especially in the north. As another measure of this intensification, the highest *Z* score increases from 11.6 in 1988 to 17.8 in 2002.

Table 1 *Aquaculture area in the study area, 1982–2002*

Year	Area (ha)
1982	5637
1988	7431
1994	7430
2002	4010

Questionnaire Survey

Tables 2 to 4 itemize responses to the survey questions. Table 2 shows that 77 percent of the surveyed farmers are currently engaged in aquaculture, 69 percent have a minimum of eleven years of experience in aquaculture farming, and 33 percent have abandoned aquaculture at least once during the past ten years. Compared to the general population in Taiwan, these farmers are older (only 13 percent are younger than 40 years old) and less educated (92 percent have ≤ 12 years of education). The great majority (72 percent) of those surveyed own the aquaculture land they

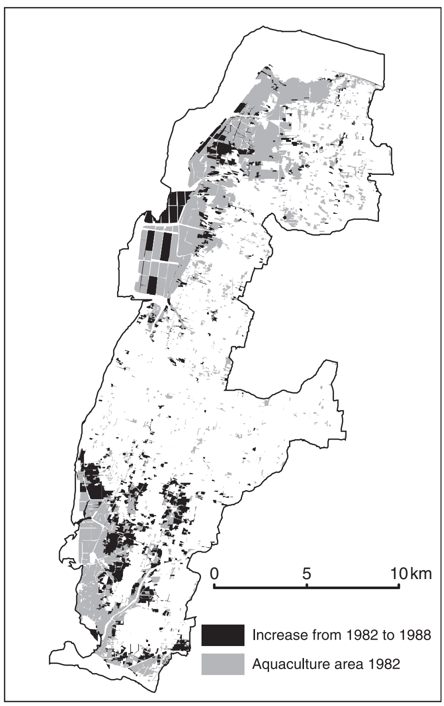

Figure 3 *Increase of aquaculture areas from 1982 to 1988.*

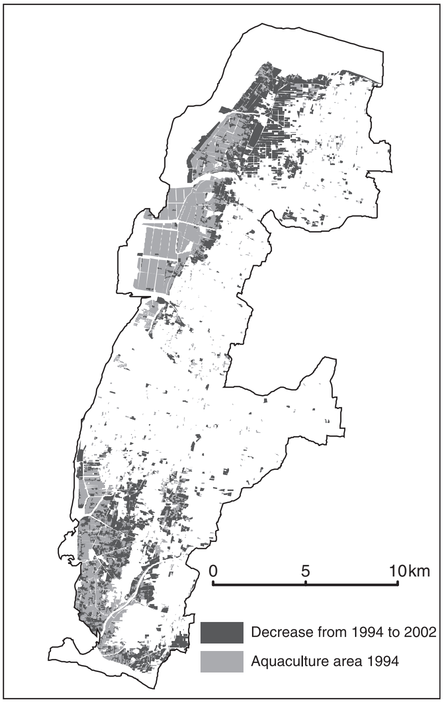

Figure 4 *Decrease of aquaculture areas from 1994 to 2002.*

farm, but 80 percent have fishponds that are smaller than three hectares.

With respect to the environmental factors, Table 3 shows that 45 percent of the surveyed farmers consider the supply of fresh water inadequate, 56 percent consider the quality of water bad, nearly 90 percent describe the problems of fish diseases and land subsidence as either fairly serious or serious, and 46 percent suffer frequent damages from typhoons. Additionally, 50 percent believe that the new naphtha cracker complex built by Formosa Petrochemical Corporation, one of the world's largest petrochemical companies, has had a serious impact on the local environment.

Table 4 shows that two-thirds of the surveyed farmers do not have enough income to pay for the household expenses, do not have enough capital to cover the farming costs, and are willing to switch to a different land use or a different job if given the opportunity. Though 87 percent agree that market price affects their decision making, only 33 percent agree that government policies affect their decision making.

Chi-square tests between cross-tabulated variables reveal a number of interesting trends between the demographic characteristics of the surveyed farmers and their views on the environmental and economic factors. Farmers with a higher level of education are more likely to rank the quality of water as bad. They are also more likely to experiment with new farming technologies, to consider government policies in their decision making, and to switch to a different job. Farmers who have spent more years in aquaculture are less likely to experiment with new farming technologies and to rank the quality of water as bad. These associations between variables are all significant statistically at the 5 percent level.

Of eighty-seven farmers in the survey, twenty-nine have abandoned aquaculture at least once during the past ten years and fifty-eight have not. Using the dependent variable (Y) that separates these two categories of farmers, the stepwise logistic regression model includes three predictive variables of size of fishpond (X_{11}), income from other sources (X_{22}), and age (X_3). The model is significant at the 1 percent level (percent correct estimation $= 89$, pseudo-$R^2 = 0.43$), and the predictive variables are significant at either the 1 percent level (X_{11} and X_{22}) or the 5 percent level (X_3). The model suggests that farmers who have abandoned aquaculture in the past are more likely to have small fishponds, to have income from other sources, and to be in the older age categories.

Discussion and Conclusions

Economic Factors

Commercial aquaculture in Taiwan, including in our study area, expanded in the 1980s primarily because of the opening of export markets in Japan for eel and shrimp. During the past two decades, however, Taiwan has lost its competitive advantage in both shrimp and eel exports.

Studies of intensive shrimp farming among Asian countries have ranked Taiwan below Thailand and Indonesia in financial performance (Kongkeo 1997) and below Thailand, Sri Lanka, Malaysia, and Indonesia in cost of production per kilogram of shrimp (Ling, Leung, and Shang 1999). Although the cost share of feed is lower in Taiwan than in other Asian countries, this relative advantage is offset by

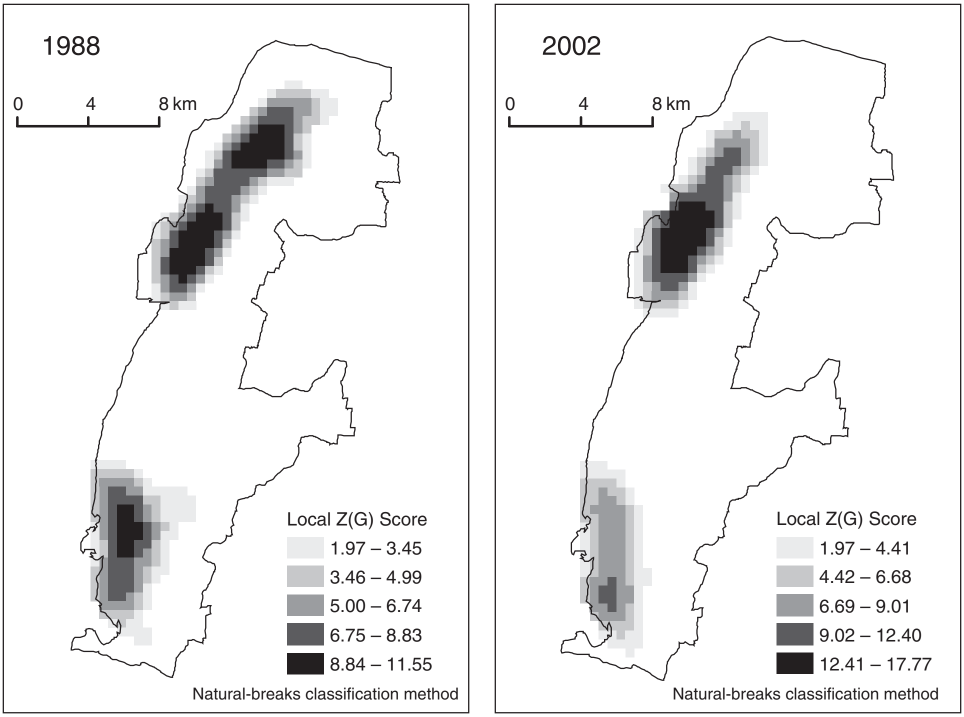

Figure 5 *Spatial clustering of high-value cells in 1988 and 2002 based on the Z scores of local G-statistics.*

higher costs of input factors such as depreciation (e.g., the high costs of construction and farm equipment) and energy power. In 1997, 60 percent of shrimp imported into Japan, the world's largest importer of shrimp, came from Thailand, Indonesia, India, and China; Taiwan was not even listed among the source countries (Traesupap, Matsuda, and Shima 1999).

Thailand has been the world's leading shrimp exporter since 1991 (Flaherty and Karnjanakesorn 1995). Pushed by investment from Taiwanese businessmen in the 1980s, intensive shrimp culture quickly spread from the upper Gulf of Thailand coast to both coasts of southern Thailand, resulting in a far more dramatic expansion than in our study area a decade earlier. Thailand has experienced aquaculture-related environmental problems such as water pollution and destruction of mangrove forests (Flaherty and Karnjanakesorn 1995; Dierberg and Kiattisimkul 1996). But shrimp aquaculture has continued to expand. It is unlikely that Taiwan can regain its competitive advantage in shrimp exports against countries such as Thailand.

Taiwan's eel farming has also faced strong competition from China. According to a comparative study of eel aquaculture in Taiwan, Japan, and China, Taiwan led in competitiveness between 1990 and 1993 but has lost its position to China since 1994 (Lee et al. 2003). As a result, Taiwan's share in the Japanese eel market dropped from 52 percent in 1990 to 7 percent in 1999 (Lee et al. 2003). During the same time period, China's share increased from 9 to 73 percent. In recent years, Taiwan's eel exports to Japan have been largely limited to fresh eel in the summer months. (Fresh eel is preferred by the Japanese who are willing to pay higher prices.)

Aquaculture farmers in our survey may or may not be aware of the loss of Taiwan's competitive advantage in aquaculture exports. They are separated from the export market by the wholesalers and exporters. But our survey results do suggest that Taiwan's weak position in the export market has seriously impacted the

Table 2 *Questionnaire results—Category 1: Background information*

1. *Are you currently engaged in aquaculture farming?*
   Yes (67), No (20)
2. *Have you abandoned aquaculture farming during the past 10 years?*
   Yes (29), No (58)
3. *Age?*
   $\leq$39 (11), 40–49 (27), 50–59 (27), $\geq$60 (22)
4. *Education level?*
   Illiterate (8), $\leq$6 years of education (29), 6–9 (25), 9–12 (18), >12 (7)
5. *Years in aquaculture farming?*
   $\leq$5 (3), 6–10 (24), 11–15 (29), 16–20 (8), >20 (23)
6. *Other than the harvesting time, can you take care of aquaculture farming by yourself?*
   Yes (72), No (15)
7. *What is the current use of your fishpond if you are not currently engaged in aquaculture farming?*
   Abandoned the fishpond (14), Have renters (6)
8. *Location of your fishpond?*
   Mailiao Township (15), Taisi Township (26), Kohu Township (46)
9. *Time of past abandonment?*
   10 years ago (4), 8 years ago (5), 7 years ago (3), 6 years ago (4), 5 years ago (6), 4 years ago (3), 3 years ago (3), 2 years ago (1)
10. *Land ownership?*
    Sole owner (63), Joint owner (2), Renter (12), A mix of the above (10)
11. *Size of fishpond?*
    $\leq$0.9 chia[a] (17), 1–1.9 chia (30), 2–2.9 chia (23), $\geq$3 chia (17)

Note: Number of responses are in parentheses.
[a] *1 chia equals 9,699 m^2 or 0.9699 ha.*

economic well-being of aquaculture farmers. Two-thirds of the surveyed farmers claim that aquaculture is not generating enough income to pay for the household expenses; as a result,

Table 3 *Questionnaire results—Category 2: Environmental factors*

12. *Have you raised, or do you raise, fish in brackish water, or fresh water, or both?*
    Brackish water (53), Fresh water (28), Both (6)
13. *Is it easy to get fresh water in your farming area?*
    Easy (22), Fairly easy (26), Difficult (39)
14. *Is it easy to get salt water in your farming area?*
    Easy (52), Fairly easy (7), Difficult (0)
15. *How serious is the fish disease problem locally?*
    Not serious (10), Fairly serious (36), Serious (41)
16. *How do you rate the local water quality for aquaculture farming?*
    Good (2), Fair (36), Bad (49)
17. *How serious is the land subsidence problem locally?*
    Not serious (9), Fairly serious (26), Serious (52)
18. *How often has your fishpond been damaged by typhoon?*
    Often (40), Occasionally (39), Never (8)
19. *What is the extent of impact that the new Formosa Petrochemical Corporation has brought to your local environment?*
    No impact (8), Some impact (35), Serious impact (44)

Note: Number of responses are in parentheses.

Table 4 *Questionnaire results—Category 3: Economic factors*

20. *Is the income from aquaculture farming enough to cover your household expenses?*
    Enough (13), Usually enough (18), Not enough (56)
21. *Do you have enough capital to pay for the farming costs?*
    Enough (18), Usually enough (9), Not enough (60)
22. *Income from other sources?*
    Yes (50), No (37)
23. *Will you consider switching from aquaculture to a more profitable land use type?*
    Yes (60), No (27)
24. *Will you consider switching from aquaculture to a different, higher-income job?*
    Yes (57), No (30)
25. *Are you willing to experiment with new aquaculture farming technologies?*
    Yes (57), No (30)
26. *Does the market price influence your decision-making in aquaculture farming?*
    Yes (76), No (11)
27. *Does the government policy affect your decision-making in aquaculture farming?*
    Yes (29), No (58)

Note: Number of responses are in parentheses.

many of them have to hold other jobs to supplement their income. And, according to the regression model, farmers who have income from other sources are more likely to have abandoned aquaculture during the past ten years.

Environmental Factors

In Taiwan and elsewhere, aquaculture has been linked to various regional and local environmental problems (Tisdell 1999). In our study area, land subsidence, apparently caused by the heavy use of groundwater, has received as much attention as the problems of fish diseases, water quality, and fresh water supply. In 1992 the Taiwan government issued *Guidance for Aquaculture Development*, a set of regulations designed to stop illegal aquaculture farms, to prevent land subsidence, and to improve aquaculture management. Also in the early 1990s a government report recorded the worst land subsidence in Yunlin as having a magnitude of 1.7 meters between 1985 and 1994. This report and pictures of slumping old buildings brought the problem to the public's attention. More recent data from the monitoring wells show a drop of water table from 0.2 to 0.45 meter between 1992 and 1997. Taiwan's Bureau of Water Resources is currently mapping the distribution of groundwater and is collecting data on the interaction between surface water and groundwater. Until both data sets become available, it will be difficult to quantify the relationship between aquaculture and land subsidence.

Nearly half of the farmers we interviewed believe that the new naphtha cracker plant built by Formosa Petrochemical Corporation has had a serious impact on the local environment. Prior to the approval of the plant, environmental impact studies did raise concerns about the plant's potential for water pollution. But no scientific data have been published to shed light on the nature and extent of the impact since the plant went into operation in 2000. Obviously, monitoring the plant's environmental impact is an important issue.

Unlike economic factors, which can impact nearly every farmer, environmental problems tend to affect some farmers more than others. It will be useful in future studies to investigate how farmers deal with real and perceived environmental problems such as fresh water supply and pollution. Abandoning aquaculture is one option, but there are other options such as relocation and capital investment. Decisions made by individual farmers can ultimately affect the spatial pattern of aquaculture.

Risk Takers and Aquaculture

Compared to other land-use changes, the changes of aquaculture areas in our study area are fast and dramatic: an increase of 33 percent from 1982 to 1988 and a decrease of 46 percent from 1994 to 2002. This fast pace may be attributed to a number of factors. One factor, which is somewhat unique with aquaculture, is the risk-taking phenomenon that has been reported in the United States during the 1970s and 1980s (Stickney 1996) and in Hong Kong during the 1990s (Lai and Lam 1999). When aquaculture is profitable, it tends to attract people to venture into aquaculture farming—people who often do not have sufficient knowledge and skills. The minimal requirement of land and relatively low capital investment for aquaculture encourage this risk-taking behavior. We suspect that risk takers are at least partially responsible for the rapid changes of aquaculture in our study area. When prices for eel, shrimp, and other species were high, these risk takers could afford to pay for higher production costs of installing pipes and operating at inland locations in order to make quick profits. When prices dropped and production costs became even higher, many of them simply abandoned aquaculture farming. We have no data in this study to substantiate this risk-taking phenomenon, but it is certainly a worthwhile topic for future studies.

Future of Yunlin's Aquaculture

Taiwan's economy has undergone major structural changes toward high technology and service industries during the past two decades. Like the traditional food-processing industry, aquaculture has lost its appeal on the island. Many aquaculture farmers have either abandoned their fishponds or converted them into other land uses under government incentive programs. For example, Ilan County in the northeast of the island had 40 to 80 percent abandoned fishponds during the 1990s. Instead of devising programs to save aquaculture, local government officials and farmers have been actively promoting tourism, whale watching, and sport fishing. These alternatives to aquaculture, especially tourism, appear to have been successful so far.

Our survey results suggest that, if given better opportunities, many farmers are ready to abandon aquaculture for a different land use or a different job. But unlike Ilan County, which is only one hour away from the Taipei metropolis, our study area is far from any major urban centers. It is therefore more difficult to develop tourism or to create new jobs in this area. (Formosa Petrochemical Corporation's new plant has created some new jobs locally, but many of its workers are from Southeast Asian countries.) Two other factors are also in favor of continuing aquaculture in Yunlin, albeit at a smaller scale. First, our study area has a strong tradition in aquaculture, especially clam farming in the north. Because clam is for the domestic market, clam farming is more stable and sustainable than shrimp farming. Second, the Taiwan government has continued to introduce new biotechnologies and to offer low-interest loans to aquaculture farmers to upgrade their production methods (Liao and Chao 1997). Two-thirds of those surveyed, especially the younger and better-educated farmers, are willing to experiment with new technologies. This survey finding is consistent with studies of diffusion of innovations that suggest that earlier adopters of technologies tend to have more years of formal education (Rogers 1995; Moseley 2000). New technologies can conceivably increase productivity and reduce production costs, thus preserving aquaculture as a viable livelihood. ■

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