RICE-FISH CULTURE IN NORTHEAST THAILAND: STABILITY AND SUSTAINABILITY

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INTRODUCTION

The small-scale farmers of northeast Thailand are the poorest in the country. One crop of rice is grown during the rainy season. Upland crops (e.g., peanuts and corn) are often grown in rain-fed areas during the dry season, while either an upland crop or a second crop of rice is grown during the dry season in irrigated areas. Traditional and locally improved varieties are used. Soils are poor, fertilizer levels are low, and some pesticides are used. Fish have recently been introduced to rice paddies and it is hypothesized that this increase in diversity will increase income, decrease fertilizer and pesticide use, and increase system stability and sustainability. This paper describes both the farming systems methodology used to test these hypotheses and the preliminary results.

History of Rice-Fish Culture

The culture of rice and fish together has probably existed since the first farmers planted rice in the lowland swamps where they had previously harvested fish. In China, rice-fish culture can be dated to the middle of the Han Dynasty (A.D. 100) (Li 1986), while in southeast Asia, rice-fish culture may have been introduced 1,500 years ago from India. In Indonesia, modern rice-fish culture was started in the mid-nineteenth century (for excellent reviews, see Khoo and Tan 1980, and Ardiwinata 1957).

Fish are important nutritionally and economically to many small farmers in Asia. The fish harvested from rice paddies are often farmers' main protein source. Fish in rice paddies are also important economically, and benefits are often greater to tenant farmers than to owners (Khoo and Tan 1980). However, fish production in paddy fields has declined sharply in the past 20 years. Indications from Indonesia (Koesoemadinata 1980) and Malaysia (Khoo and Tan 1977) are that the introduction of double and triple rice cropping along with increased fertilizer and pesticide use have been the contributing causes. Similar decreases have also occurred in China (Li 1986).

In Thailand, the integrated cultivation of rice and fish has been practiced for more than 200 years. Early applications were dependent upon capturing wild seed-fish for stocking the rice fields. In the 1940s the Department of Fisheries started to promote rice-fish culture by providing seed-fish and extending technologies. Rice-fish farming proliferated in the central plains where fish yields ranged from 137 to 304 kg/ha/crop. Rice yields were enhanced by 25% to 30% in fields integrating fish. However, the introduction of high-yielding varieties of rice and increased fertilizer and pesticide applications resulted in near collapse of rice-fish culture in the central plains of Thailand in the 1970s. Farmers either separated their rice and fish operations or stopped raising fish. Moreover, the Centre for Rice-Fish Culture Research, established in 1968 to develop appropriate technologies, was closed in 1974 (Fedoruk and Lilaphatra 1985).

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Recent research in rice-fish culture has concentrated on developing techniques to integrate fish back into rice production. These management techniques involve minimizing the harmful effects of fertilizer and pesticides on fish (Dela Cruz 1980; Estores et al. 1980; Li 1986; Singh et al. 1980).

In northeast Thailand, rice-fish production is now increasing. Reports from various rural development workers indicate a rapid expansion of the fish production in rice paddies. What is unique about this development is that it is occurring spontaneously among farmers. Mixed rice-fish culture is not being pushed by any development program but is being aided by a number of government and nongovernment development organizations. The causes of the expansion are not completely known although some are discussed in this paper.

Since 1984, the Farming Systems Research Institute, Department of Agriculture, Thailand, and CUSO fisheries cooperants have been conducting on-farm research with rice-fish farmers in northeast Thailand. This research is designed to test the hypothesis that introducing fish into farming systems of this region will increase diversity, resulting in greater stability and sustainability, both ecologically and economically.

Theoretical Concepts of Ecosystem Stability

One of the more popular themes of ecosystem theory is the relationship between species diversity and system stability (Odum 1971). In its basic form, this theory suggests that simple systems with few species are less stable than more complex systems with a greater number of species. However, this theory has generated considerable argument over: (1) the methods of measuring diversity, (2) the unit to measure (e.g., tropic level, related taxa, guilds, etc.), and (3) the mechanisms which lead to stability. The most recent consensus appears to be that increased diversity does not necessarily produce stability. It is, however, the connections or linkages between species that are more important for system stability. (See Connell and Sousa 1983, King and Pimm 1983, and Margalef and Gutiérrez 1983 for examples of recent arguments.)

In agricultural systems, the common dogma has been that minimal diversity is best. Simple systems are easier to manage and yield a higher food and economic return to human societies. Recent problems of diseases and pests, market instability, and environmental degradation related to these simple systems indicate that monocultural agricultural systems are not stable, but instead are maintained by large inputs of energy and materials.

There is increased interest in stability and sustainability of agricultural systems (Douglas 1984a). However, sustainability when applied to agriculture has many meanings. Douglas (1984b) identified three schools of thought related to agricultural sustainability: food self-sufficiency, stewardship, and community. While Altieri et al. (1984) have listed the desirable elements of sustainable agriculture (conserving renewable resources, adapting crops and associated components to the environment, and achieving and maintaining relatively high but sustainable, levels of productivity), there has been little effort to quantify these elements. Stability is used in plant breeding as a measure of cultivar variability over location and time, but stability is not normally used in agriculture as a systems property.

Conway (1985) identifies four systems properties that are useful in defining agroecosystems:

1. *Productivity* is the net increment in valued product per unit of input, and is commonly measured as annual yield, net income, or gross margin.
2. *Stability* is the degree to which productivity remains constant in spite of normal, small-scale fluctuations in environmental variables; it is most conveniently measured by the reciprocal of the coefficient of variation in productivity.
3. *Sustainability* can be defined as the ability of a system to maintain its productivity when subject to stress or perturbation. A

stress is here defined as a regular, sometimes continuous, relatively small and predictable disturbance. A perturbation, by contrast, is an irregular, infrequent, relatively large and unpredictable disturbance. Unfortunately, measurement is difficult and can often only be done retrospectively. Lack of sustainability may be indicated by declining productivity but, equally as experience suggests, collapse may come suddenly and without warning.

4. *Equitability* is a measure of how evenly the products of the agroecosystems are distributed among its human beneficiaries. The more equitable the system the more evenly are the agricultural products, the food or the income or the resources, shared among the population of the farm, village, region or nation. It can be represented by a statistical distribution or by a measure such as the Gini coefficient.

These properties are illustrated graphically in Figure 1. There are also significant trade-offs between productivity and stability on one hand, and sustainability and equitability on the other.

RESEARCH METHODS

This paper reports selected results from larger studies of rice-fish culture. These studies are part of programs to increase farmers' income through improved and diversified agricultural production. These studies have focused on current farmers' practices, research in association with farmers, and extension to other farmers. This work has been carried out by the Farming Systems Research Institute (FSRI) of the Thailand Department of Agriculture.

FSRI has used the Farming Systems (FS) methodology initially developed by the International Rice Research Institute and subsequently modified by practitioners in various Asian countries (Agricultural Research Office, Ministry of Agriculture and Food 1985; Zandstra et al. 1981). This method stresses a high degree of farmer involvement from the beginning of the study and continued farmer involvement throughout the experiment. The FS approach initially involves a site description obtained with formal or informal survey techniques to determine relevant background information on agronomic, economic, and social aspects of the farm studied. This is followed by on-farm experiments which are designed using the results of the site description and in close collaboration with farmers. The experiments are monitored and data on relevant biological, economic and social parameters are collected.

This research has been carried out in close cooperation with farmers in northeast Thailand at two sites, Sakon Nakhon and Ubon Ratchathani (Figure 2). At both sites, irrigated and rain-fed farms were studied. The fish introduced by farmers into paddies were common carp (*Cyprinus carpio*) at both sites, tilapia (*Sarotherodon nilotica*) at Sakon Nakhon, a hybrid of *S. niloticus* and *S. mossambica* at Ubon, and silver barb (*Puntius gonionotus*) at both sites. In Ubon, several bigheaded carp (*Aristichthys nobilis*) were also included in 1985 and 1986.

Due to the short timeframe of the study, it is not possible to measure changes in stability and sustainability. Indicators of stability are, however, examined: farm productivity, farm income, incidence of pests and diseases, requirements for chemical inputs, and farmers' perceptions of the system.

Site Descriptions

Sakon Nakhon

Farmers who were raising fish in paddies were initially identified by questioning villagers throughout the province. Once rice-fish farmers were identified, the interviewers spent several hours in general discussion with each before asking if they would be willing to participate in a follow-up interview. The informal interview was carried out after the first or second visit using a predetermined set of questions as a guide. Additional information was obtained during informal follow-up visits. Thirty informants were interviewed between July 1984 and January 1985.

Ubon Ratchathani

There was no need to carry out a site description at Ubon as it was available from previous cropping systems research.

Experiments

Sakon Nakhon

Based on the survey results, an experiment was designed to assess the role of fish in pest control. Three farmers from each of the irrigated and nonirrigated areas were selected. One farmer used pesticide on his nonfish field and was dropped from the analysis. On each farm, adjacent paddies which contained introduced fish and nonintroduced fish were studied. Fifty hills in each paddy were sampled for insect and disease damage eight times during the rice growing season. The fish were sampled over the season and stomach contents preserved and identified.

Ubon Ratchathani

The experiments were carried out on-farm and were superimposed trials. The experiments were designed to test the effect of fish on rice yields and monitor the economic performance of rice-fish cropping systems compared to nonfish cropping systems. Different stocking rates were used. In 1984-85, 2,500 and 5,000 fish/ha using carp, tilapia, and puntius in a ratio of 1:2:2 were tested. In 1985-86, three rates of 2,500, 3,750, and 5,000 fish/ha using carp, tilapia, puntius, and bighead carp in a ratio of 10:5:4:1 were tested.

Data Collection

The principal method of gathering data involved weekly interviews, supported as much as possible by related measurements and data recorded on forms by the participating farmers. The weekly interviews were indispensable since farmers can generally remember activities of the previous week. If interviewing is delayed much longer than one week, memories begin to fade.

Attempts were made to follow fish growth by periodically measuring fish sampled from the paddies. However, there were considerable difficulties. While fish in rice paddies can be easily sampled in the trenches or sumps if the water level is dropped, this practice is not possible under on-farm conditions. Furthermore, farmers will often add branches to the trenches to prevent fishing (theft) in these areas. Additionally, fish are removed continuously for home consumption and marketing. Control of fish stocking levels in some fields was difficult when adult and juvenile fish remained from the previous season. The level of stocking was estimated in these cases. Fish weights were determined from fish caught while the researcher was present so that production (in weight) could be estimated from farmers' reports of the number and size of fish caught each week.

Rice yields were estimated from crop cuts obtained by marking out sample plots of 8 m^2, with 4 samples per rai[2]. The cooperating farmers harvest the sample plots and store the seed for the researcher, who obtains weights and moisture content at a later date. Farmers also supplied their own estimates of rice yield for the whole field. Supporting measurements included measurement of the area occupied by fish fields to enable accurate calculation of stocking rates and production.

RESULTS AND DISCUSSION

Characteristics of Farms

Some demographic, climatic, and agricultural parameters representative of the two provinces included in this study are presented in Table 1. The farmers involved in the rice-fish project in both provinces appear to be representative, e.g., the average farm area of the 30 farmers interviewed in Sakon Nakhon was 3.3 ha. The farm size in the Ubon area is similar.

Glutinous rice was the predominant crop

[2] 1 rai is equivalent to 0.16 ha.

among most farmers although nonglutinous rice is often grown during the dry season under irrigated conditions. Farmers grow a number of varieties of rice: in Sakon Nakhon at least 17 different rice varieties are grown, while in Ubon 12 varieties are grown. The locally improved lines are most popular but traditional varieties are also very important. One crop of rice per season is grown in the Sakon Nakhon area, even in the irrigated area. In the irrigated area of Ubon, a second crop of rice is normally grown in the dry season, although not all the land is planted to rice at that time. Recently, low rice prices have resulted in decreased acreage planted to rice during the dry season. At both sites, the wet season (June-October) is the major rice-growing period.

Family food self-sufficiency is of major importance at both sites. Farmers normally keep 1.5 to 2 MT of rice for their own consumption. The wet-season crop, a glutinous variety, is generally used for home consumption. In irrigated areas, farmers sell most of the dry-season crop. Rice paddies are also important in supplying other foods. The Sakon Nakhon study lists rice, shrimp, crabs, snails, aquatic morning glory, and frogs as being important food items obtained from rice paddies in addition to rice and fish. Heckman (1979) points out that the rice paddies in northeast Thailand are complex ecosystems supplying a number of products to farm families. Fish are an important component in the diet in Sakon Nakhon. Most families said they consume fish at least once a day. (This survey was conducted mainly during the wet season, and results may have been different during the dry season when water and fish are much scarcer.) A number of other crops are also grown in the irrigated areas of Sakon Nakhon and Ubon. Vegetables and upland crops such as peanuts and corn are often grown during the dry season, while some rain-fed farms produced vegetable crops during the dry season. All farms had animals; chickens, buffaloes, and cows were the most important, followed by pigs and ducks.

Rice-Fish Poduction

Rice-fish culture is expanding rapidly in northeast Thailand. In Sakon Nakhon, 43% of the farmers interviewed were in their first year of production while only 10% had been involved for longer than three years. Follow-up visits to the farmers in 1985-86 indicate that more new farmers are starting rice-fish culture and those who were involved earlier are increasing the area in production. A similar trend is occurring in Ubon. In both areas, farmers' perceptions of rice-fish culture and its value to them is very positive. In Sakon Nakhon, 70% of those interviewed consider rice-fish culture very important to them. While rice-fish culture is new, fishing is not. All farmers in the study traditionally capture fish in both rice paddies and nearby waterways. Most rice paddies have fish traps at the outlets.

Few farmers in either area use pesticides on their rice. In Sakon Nakhon, 87% of the farmers did not apply pesticides. The 13% who used pesticides farmed irrigated areas and two farmers used pesticides only in paddies with no fish. Some farmers in Ubon use pesticides for crab control. Farmers appear to be very aware of the pesticide danger to fish and all indicated that they would not use pesticides on fields with fish.

There is no set method of rice-fish culture at either site. There is a wide variation in types of ponds, sumps and trenches that the farmers use. There are also wide variations in stocking rate, species mix and supplemental feeding practices. A significant conclusion from this study is that it is important for researchers to observe and understand farmers' methods, rather than designing optimal systems under experimental conditions without input from farmers.

Pests and Diseases

The preliminary data on pests and diseases in fields with and without introduced fish is presented in Table 2. While the statistical analysis is not complete, the results strongly suggest a decreased total incidence of rice pests and diseases (Figure 3) when fish are present, with the greatest reduction being in rice diseases. Subsequent research during the 1986 cropping year (Chapman et al. 1987) showed little difference in disease although the disease incidence was lower in 1986 and the diseases were different. Chapman et al. conclude that the addition of fish to rice crops can control certain insect pests, however, there is conflicting evidence for fungal diseases. The mechanisms and the fish species most responsible for the reduction in pests and possibly diseases are not yet known and require further detailed research.

Rice Yields

The crop yields of Ubon's on-farm experiments are confounded by high variability and few degrees of freedom. The variability is due to environmental (both between and within fields) and management (different farmers) factors. However, data based on crop cuts for the 1984 wet season in fields stocked with fish at 5,000/ha showed that the presence of fish accounted for a significant portion of rice production variability (Table 3). This was not so for fields stocked at lower rates.

The data based on farmers' estimates were more variable than the crop cut estimates and it was not possible to show statistically significant differences between rice yields of fields with and without fish. However, farmers in both areas maintain that fish in paddies increase rice yields. In fact, in Ubon, farmers have reduced fertilizer levels in rice-fish fields and hope to maintain the same level of rice yields.

Fish Yields

Fish production information for an irrigated area in Ubon during the wet and dry seasons is presented in Table 4. Wet-season production was only 25% of dry-season production. However, the 1984 wet season was the first season in which farmers used the rice-fish combination. The lower production is partially a result of inexperience, as some fish were lost to floods and fish were also carried over to the 1985 dry season rather than harvested. It is expected that subsequent wet-season production will increase as a result of increased experience. The total production of 134 kg/ha is considerable considering farmers' inexperience and lack of inputs. Future production should match that of centuries-old systems such as those of China which yielded 200 to 250 kg/ha (Li 1986).

Half of the fish produced were sold for food, one-third were consumed, and 13% were sold as seed fish (fingerlings). In addition, farmers were able to supply most of their needs for fingerlings to restock rice fields. The cash contribution from rice sales was considered significant by farmers. They viewed the fish as cash in the bank. While farmers would harvest almost daily for home use, they would sell fish only when money was needed. Although farmers receive a higher price for larger fish, all sizes can be sold. There is no optimal market size as in many aquacultural operations elsewhere.

There is little data on fish production in paddies which have not been stocked with fish, although farmers do capture fish from such rice paddies. Fedoruk and Lilaphatra (1985) indicate that yields of wild fish decreased from 77 to 28 kg/ha from 1975 to 1981. There is no data on other food items (shrimp, crabs, frogs, lizards, snails, etc.) traditionally harvested from rice paddies.

Economics of Rice-Fish Culture

Complete data on costs, returns, and labor were available only for four farmers from Ubon's irrigated area (see Table 5). No statistical analysis was attempted because of the data's limited degrees of freedom and wide variability. However, the data suggests that rice-fish cultures significantly affect the household and farming economics.

The value of production for both the wet and dry seasons was increased 2.5 times when fish were added to rice fields. However, expenses are substantially increased, particularly during the wet season, resulting in financial loss in the first season. A detailed examination of expenses (Table 6) indicates that they are due to trench preparation (subsidized by the project, but included in the costs), initial purchase of fingerlings, and large amounts of rice bran used for supplemental feed. These costs can be reduced by 40% if farmers dig their own trenches (as they did during the dry season) and reduce the use of bran. Bran feedings have been reduced in subsequent growing seasons, apparently because they are not cost effective. Even with high start-up costs, the rice-fish culture is slightly more profitable than rice alone. If reduced start-up costs are assumed, rice-fish culture is 2.5 times more profitable than rice alone. This allows a payoff of all start-up expenses and a profit in the first season, something very important to small farmers with no savings or access to credit.

The economic impact of rice-fish culture in the dry season is great. Lower costs for trench digging and fingerlings, as well as decreased fertilizer use, reduce overall expenses below those for rice monoculture. The resulting profitability for rice-fish cultures is more than double that of rice monocultures. Furthermore, while labor demands for rice-fish cultures are more than double those of rice monocultures, the returns to labor are greater. Farmers in Ubon have realized the value of fish in the dry season and in some fields are raising fish without rice. Survey results in Sakon Nakhon indicate that there is no conflict in labor demands between rice and fish. In Ubon, labor conflicts can occur if fish and rice are harvested at the same time.

If the results of the dry season are indicative of subsequent years, rice-fish culture offers the potential to double farm income. The farmers' appreciation of the economic values of rice-fish culture are reflected in the rapid adoption of this practice. Increased production may reduce rice and fish prices so that marketing strategies will become increasingly important.

Ecosystem Properties of Rice-Fish Cultures

Productivity

While the data from these on-farm experiments is incomplete and problematic with regard to statistical analysis, it suggests that increased agroecosystem diversity increases productivity. The addition of fish to rice paddies appears to increase both rice yields and fish production, thus increasing total yields and economic returns.

Stability

The stability of rice production in Sakon Nakhon and Ubon Ratchathani is quite high (Table 1). Rice yields in Ubon are more variable, possibly because of that region's lower rainfall. Stability of the rice-fish system cannot be determined given the short time period of this study and the rapid expansion of this practice. Middendorp and Verreth (1986) suggest that fish production is less stable than rice production. Rice and fish prices are the major factors expected to influence the stability of rice-fish culture. However, the introduction of fish into the rice system offers additional food and income sources, decreases pest incidences, may reduce fertilizer requirements (i.e., increases linkages in ecological terms), and should increase ecosystem stability.

Sustainability

It is not possible to quantify sustainability of the rice-fish system. There are, however, certain features of this farming system which suggest sustainability: (1) chemical and other external inputs are reduced, (2) it is adapted to the social environment, and (3) there are reinforcing synergistic effects on other aspects of the farming system.

Reduced Inputs. Producing fish in rice-fish culture requires a minimum of additional inputs. Feed supplements such as termites can be collected locally. Rice bran, although purchased, is a locally available resource. Farmers also add other materials such as household wastes, buffalo dung, banana pseudostems, etc. to ponds or trenches, which may supply food indirectly to fish and also enriches the adjoining rice paddies. Fish fingerlings must be purchased initially, but farmers are becoming adept at spawning and raising fingerlings and can supply most of their own fingerlings in subsequent seasons. Fish appear to reduce the incidence of disease and pests in rice, thus decreasing the need for chemical controls. Fish may also contribute to weed control. In addition, farmers are now testing whether they can reduce chemical fertilizer inputs for rice when fish are present.

Adaptable to Social Environment. Rice-fish production is an extension of traditional fishing which is carried out by many farmers in northeast Thailand. The two operations are closely integrated, as farmers will often eat and sell both wild fish and the more highly valued paddy fish. The skills of fish capture, building traps at paddy outlets, etc. are present in the community, and the labor devoted to fish rearing is often seen as recreation. In addition, many of the activities, such as fish capture, guarding, and feeding, can be carried out by children.

Synergistic Effects. The adoption of the rice-fish system may increase the commitment to farming and improve farm management in ways that rice culture alone does not. The daily half hour that farmers spend checking their fish, maintaining the water level, and repairing the dikes probably also improves the management of rice. A more dramatic impact is occurring in a rain-fed area of Sakon Nakhon. Farmers live in a village at some distance from the farm and maintain only a temporary wet-season home on the farm. However, the demands of protecting fish from theft require year-round presence on the farm. Some families are moving back to the farms and increasing dry-season food production (gardens and orchards) around the ponds, using the rice-fish paddy water for irrigation.

Equitability

Obviously a longer-term study is required to measure equitability. However, rice-fish culture's low cash requirement, fast payoff in food and cash, and high labor requirement make it attractive to poor farmers in northeast Thailand, and interest is particularly high among small-scale poor farmers. In Sakon Nakhon, the farmers who were least positive about this system were those who had an off-farm source of income. The question of equitability between sexes is also an important issue. Fish production is very much a male activity. Women and girls very seldom participate in fish rearing activities. The benefits, however, accrue to the entire household, primarily in increased protein availability.

CONCLUSION

The introduction of three fish species into rice paddies appears to increase the productivity of both rice and fish in farming operations in northeast Thailand. Evidence of decreased pest and disease incidence, increased ecosystem linkages within the farming system, minimum reliance on external inputs, and farmers' ready acceptance of rice-fish culture all suggest that increased stability and sustainability may characterize farming systems which incorporate this mixed-species practice.

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Table 1. Relevant Demographic, Climatic, and Agricultural Parameters for Sakon Nakhon and Ubon Ratchathani Provinces,* NE Thailand

Population density	80/km²	
Population growth rate	3-4%	
Family size	6.0-6.5 (SN)	7 (UR)
Farm size	20-25 rai (3.2-4.0 ha)	
Rainfall	1,500 (SN)	1,400 (UR)
Drought days	60-80	
Rice crop	Glutinous 70%	
Rice stability		
Coefficient of variation of area planted to paddy (1973-77)	10%	
Coefficient of variation of paddy yield/rai (1973-77)	10% (SN)	21-30% (UR)

1 rai = 0.16 ha

SN = Sakon Nakhon

UR = Ubon Ratchathani

* Values for the two provinces are similar unless noted.

All values after Khon Khaen University-Ford Cropping Systems Project, 1982.

Table 2. Incidence of Pests and Diseases in Rice Paddies in Sakon Nakhon, NE Thailand, With and Without Introduced Fish

	Cultured fish	No cultured fish
	(numbers represent $\overline{X}$ farm/season)	
Diseases		
Narrow brown leaf spot (*Cercospora orizae*)	91.2	210.4
Sheath blight (*Rhizoctonia solani*)	33.8	102.4
Bacterial leaf blight (*Xanthomonas campestris*)	30.8	74.6
Pests		
Leaf folder (*Cnaphalocrocis medinalis*)	20.6	28.6
Leaf roller* (*Cnaphalocrocis medinalis*)	9.2	19.4
Whorl maggot (*Hydrellia* spp.)	16.2	0.6
Stem borer (*Chilo suppressalis*)	3.0	1.2
Gall midge (*Orseolia oryzae*)	20.6	20.4

* Although the leaf roller and leaf folder cause different symptoms in affected plants, they are probably the same species.

Table 3. Anova of Rice Yields (8-m^2 Samples) from Farmers' Fields With* and Without Stocked Fish at Dom Noi, Ubon Ratchathani, NE Thailand, Wet Season 1984

Source of variation	Degrees of freedom	Mean square	F
Farmers	5	1.862	43.289 (p < .001)
Fish	1	1.769	27.541 (p < .005)
Farmer-fish interaction	5	0.064	1.494 (NS)
Within treatment	13	0.080	7.428 (p < .001)
Error	17	0.011	
Total	41		

* Fields with fish were stocked at 5,000 fish/ha.

Table 4. Annual (1984-85) Fish Production in Rice-Fish Fields in an Irrigated Area, Ubon Ratchathani, NE Thailand (Based on Data from Six Farmers)

Average	Wet season 1984		Dry season 1985		Total	
Fish consumed						
production (kg/ha; %)*	13.7	9.5%	35.4	27.0%	49.1	36.4%
Fish sold						
production (kg/ha; %)	16.0	11.1%	52.0	39.7%	68.0	50.8%
income (baht/ha; U.S.$/ha)†	437	$19.12	1,491	$52.76	1,928	$71.88
Seed fish (sold/given away)						
production (kg/ha; %)			16.8		16.8	12.8%
income (baht/ha; U.S.$/ha)			830	$29.37	830	$29.37
Total						
production (kg/ha; %)	29.7	20.5%	104.2	79.5%	133.9	
income (baht/ha; U.S.$/ha)	437	$19.12	2,321	$82.13	2,758	$101.25

* Left column of each pair expressed in kg/ha; right column expressed in %.
† Left column of each pair expressed in baht/ha; right column expressed in U.S.$/ha.

U.S. $1.00 = 26 Thai bahts.

Table 5. **Economics of Rice-Fish and Rice-Only Production during 1984-85 on Four Farms in Lam Dom Noi Irrigated Area Ubon Ratchathani, NE Thailand**

	1984 Wet season	1985* Dry season	Total
	(baht/ha with U.S. $/ha in parentheses)		
Total value†			
Rice-fish	3,229 (124.19)	6,218 (239.15)	9,447 (363.34)
Rice	1,130 (43.46)	2,512 (96.61)	3,642 (140.07)
Expenses			
Rice-fish	6,567 (287.27)	1,101 (40.39)	7,668 (327.66)
Rice-fish‡	3,940 (172.36)		5,041 (212.75)
Rice	384 (16.80)	1,498 (54.95)	1,882 (71.75)
Net profit			
Rice-fish	-3,338 (-128.38)	5,117 (196.80)	1,779 (68.42)
Rice-fish‡	-711 (-27.34)		4,406 (169.46)
Rice	746 (28.69)	1,014 (39.00)	1,760 (67.69)
Labor requirements		(in worker days)	
Labor			
Rice-fish	161	113§	274
Rice	72	55	27
Return to labor			
Rice-fish	-21 (-0.81)	45 (1.74)	6 (0.25)
Rice	10 (0.40)	18 (0.71)	14 (0.53)

* Data from three farms only; one farmer grew no dry-season rice.
† Includes fish and rice consumed by the farm family.
‡ Minus 40% start-up costs.
§ Includes digging of trenches in new fish fields.

U.S. $1.00 = 26 Thai bahts.

Table 6. Additional Cost and Labor Associated with Rice-Fish Culture during 1984-85 for Five Farmers in Lam Dom Noi Irrigated Area, Ubon Ratchathani, NE Thailand

	1984 Wet season	1985 Dry season
Cost	(bahts/ha)	
Trench preparation	1,520	
Fish fingerlings	3,793	525
Rice bran	902	519
Total	6,215	1,044
Labor	(worker days/ha)	
Trench preparation and maintenance	108.0	n.a.
Feedings	13.1	13.8
Fishing	22.5	29.7
Total	143.6	43.5

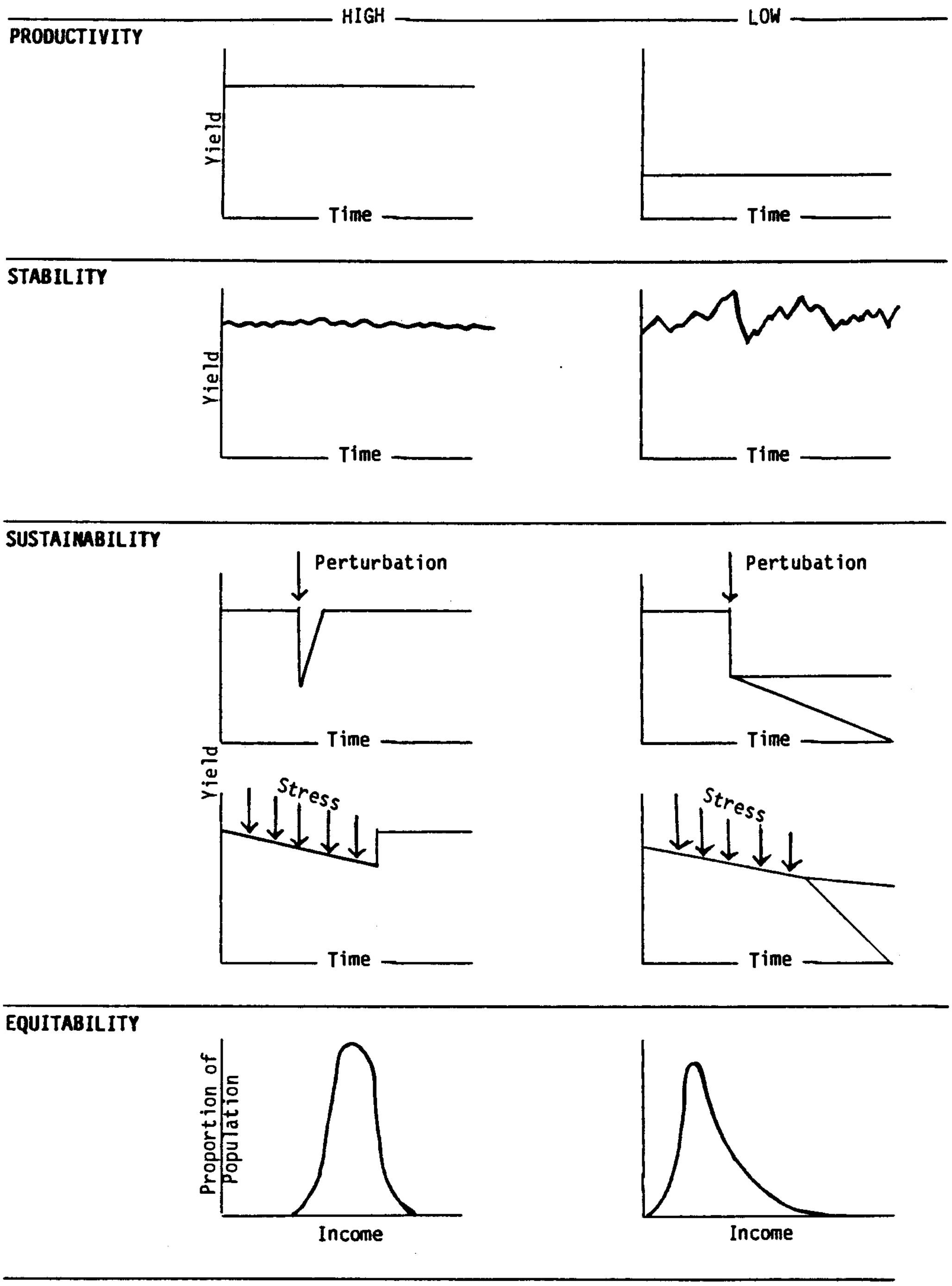

Figure 1. The system properties of agroecosystems

Source: Conway (1985)

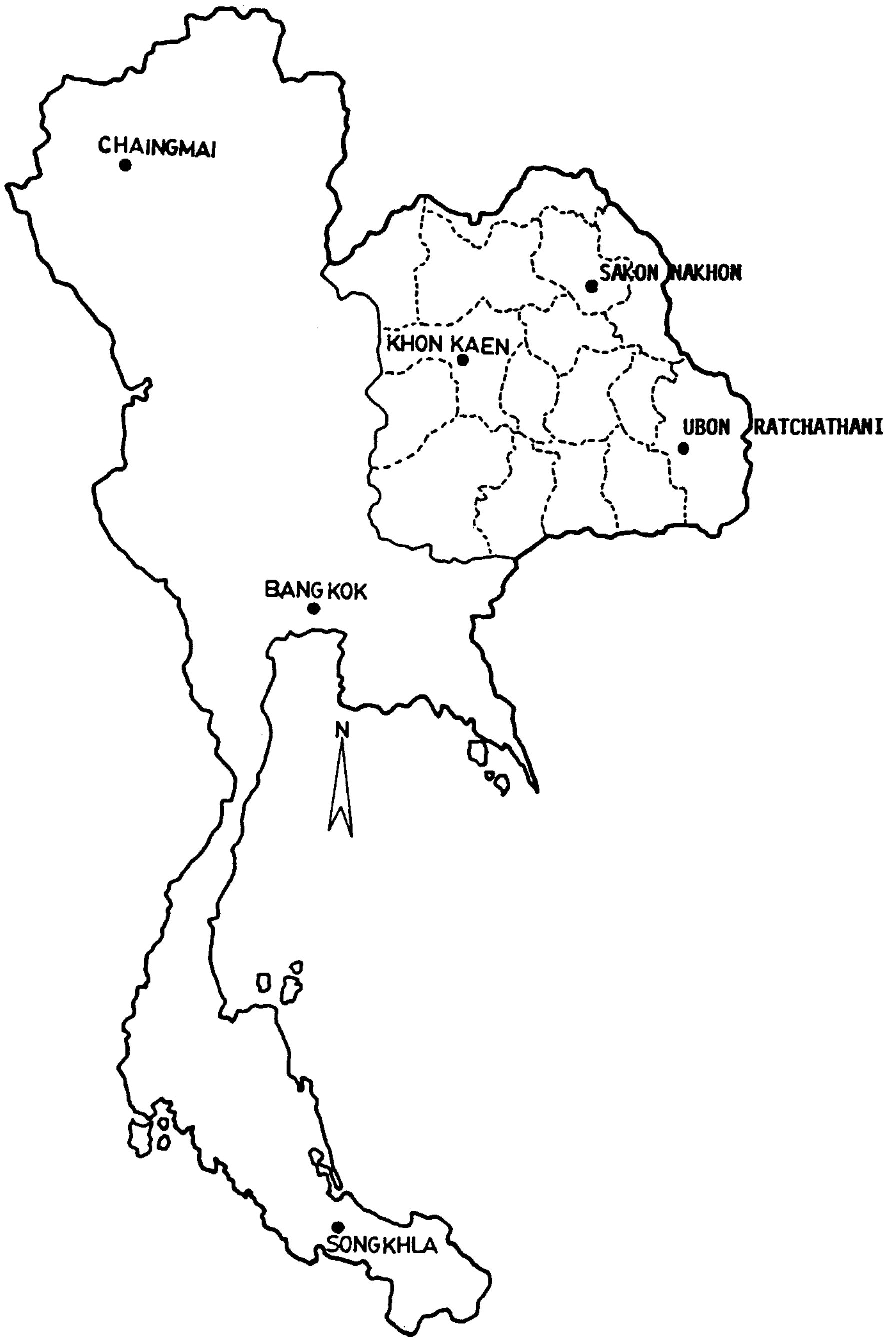

Figure 2. Map of Thailand showing the northeast region