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FARMING SYSTEMS BASED ANNUAL-CROP DEVELOPMENT[1/]

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INTRODUCTION

This paper deals with symbiotic relationships between annual crops and other components of the farm system. Symbiosis is defined by ecologists as "the association of dissimilar organisms to their mutual advantage", to the layman it means a way of getting something for nothing and for the purpose here it is best described as beneficial interactions between annual crops and other components of the farm system that improve the performance of the system as a whole. Symbiosis relies on system interactions, in this case interactions between annual crops and other components of the rainfed farm agro-ecosystem in the Korat Plateau of Northeast Thailand.

The typical farm agroecosystem of the Northeast is a small, predominantly crop-based, mixed-farm with 80 per cent of agricultural income coming from cropping activities, the remainder accruing from the sale of livestock and fish, production of silk and charcoal, sale of forest products, etc. The major annual crops are rice for subsistence and sale in the paddy land and cassava or kenaf on the upland. Ninety-five percent of the region has no irrigation and the crop production environment is characterized by extremely poor soils and rainfall with extremely high annual variability (Craig and Pisone, 1985). Annual crop production strategies and other components of the farm system have co-evolved in response to local agro-ecological conditions and farm-family requirements. Staggered planting dates, cultural practices and the crops grown are the most common farmer strategies for dealing with this unproductive and highly variable annual crop production environment.

As shown in Table 1, both the major annual crops are ideally suited as components of the agroecosystem. In rice, for instance, photo-sensitive varieties are used enabling planting dates to be adjusted depending on if and when there is sufficient water for transplanting, the fields are banded to maintain standing water to enhance nutrient availability, farmers keep a number of years rice supply in their barns to carry them over years of low production and they use minimal purchased inputs to reduce risk

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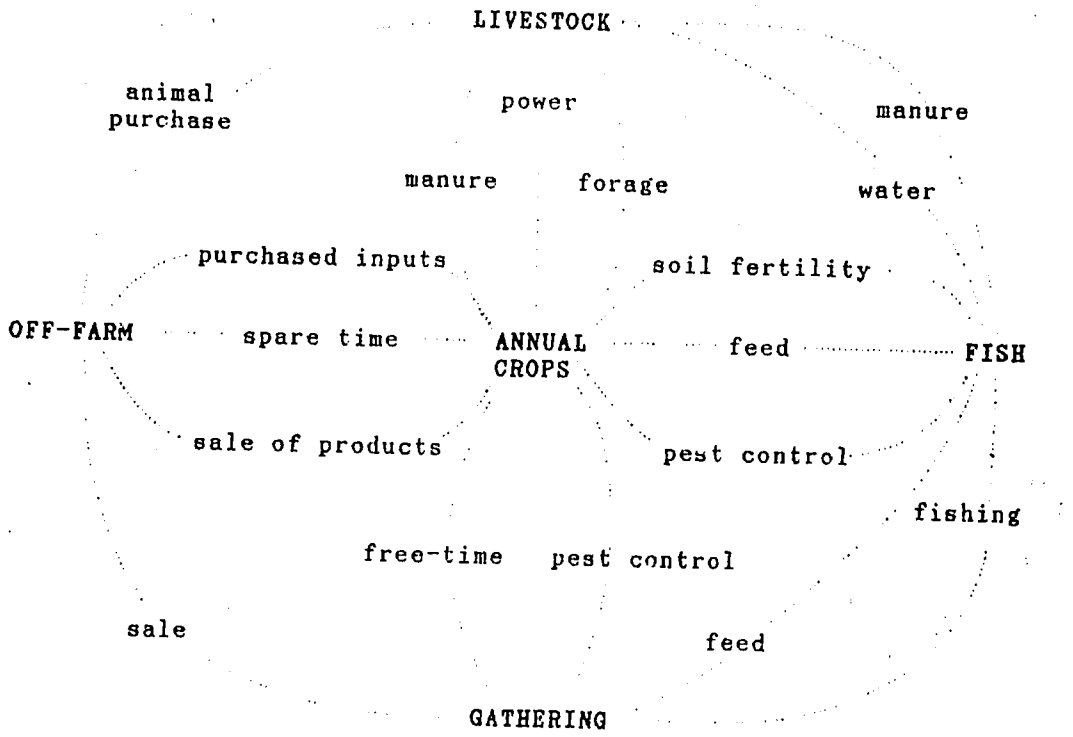
Table 1. Suitability of the two major annual crops to the crop production environment in Northeast Thailand.

PADDY RICE	PREVAILING CONDITION	CASSAVA
Capable of growing under reduced, water-logged conditions.	POOR SOILS	Efficient extractor of nutrients in infertile soils.
Photosensitive varieties can be kept in seed-bed until rain sufficient.	VARIABLE RAINFALL	Tolerant to drought
Can be grown under low input levels.	INSUFFICIENT CAPITAL	Low or zero inputs required.
Very little labor required between planting and harvest.	OFF-FARM ACTIVITY	Two planting times and harvest flexible according to family labor availability.
Produces straw for livestock and fish, crabs, etc. are collected in the paddy.	MIXED FARM	Labor peaks don't conflict with other farm enterprises.

in drought or flood years when they may lose the entire crop. Cassava, the other main annual crop, also requires minimal cultural attention and cash inputs, it is tolerant to drought, thrives on infertile soils and harvesting can be adjusted to suit cash needs or family labor availability.

In addition to being ideally suited components of the agroecosystem, these crop components are also intimately linked to other components of the farm system (Figure 1) and thus improvements to annual crops can have a variety of effects that may be either beneficial or detrimental to other components of the farm system. It is the contention of this paper that the interactions between annual crops and other components in the farm system and the way the farmer manipulates them in line with his objectives has to be understood if undesirable effects are to be avoided and if beneficial or 'symbiotic' effects are to be capitalized upon.

Figure 1. Major interactions of annual crops with other components of the farm system.



UNDERSTANDING FARMER STRATEGIES FOR ANNUAL CROPS

The study and analysis of traditional farming systems is needed to identify the farmer strategies being followed in the management of important farm system interactions. Many tools were available to NERAD for this including agro-ecosystems analysis, rapid rural appraisal and other techniques that were already widely used in Thailand (Gypmantasiri, et al., 1980; Trebuil, 1982; Anonymous, 1982; Jintawet, et al., 1985; Conway, 1986).

Some of the strongest interactions in the Northeast farm agroecosystem were found to occur between annual crops and livestock (See Figure 2). Indeed, in many cases, the annual rice crop is actually maintained by the manure and draft power made available by interactions with livestock.

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Figure 2. Beneficial and detrimental interactions between annual crops and livestock in the Northeastern agroecosystem.

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          |<--- +VE   land preparation <------|
          |                                   |
          |<--- +VE   manure application <----|
          |                                   |
RICE ----|---> -VE   reduced grazing area -->|---- LIVESTOCK
          |                                   |
          |---> +VE   straw for forage ------>|
          |                                   |
          |<--- -VE   damage to crop   <------|
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NERAD has identified a number of strategies used by farmers to manipulate these crop/livestock interactions in order to maintain soil fertility (Craig, 1985). Farmers in Amphur Muang, Roi Et, for example, grow water melon with the objective of maintaining the yield of the following rice crop through the cattle manure needed by and paid for by the water melon. Other farmers carefully air dry their animal manure, which volatilizes off much of the N, but is necessary to avoid the soil pH reduction associated with the application of fresh manure. The dried manure is then generally applied intensively to a few fields each year in order to support intensive crop production for that year in those fields. This manure application is rotated around the whole farm over a number of years to spread the effect.

Obviously, there are also many farmer strategies for manipulating the crop/climate interaction that is so important for rainfed agriculture. The kenaf-rice system common in the paddy land in the central part of the region is essentially a risk-reducing strategy employed by farmers under conditions of variable rainfall. In dry years when rice planting is delayed or sometimes not even possible, farmers can leave the kenaf in the field to increase yield and thus obtain some compensation for the loss of the rice. Conversely, in wet years kenaf yields are lower due to early harvesting but this is compensated for by improved rice yields.

Pest control strategies for rice commonly employed by farmers are essentially a manipulation of the annual-crop/farm-family subsistence interaction. Paddy crabs, small insects, birds and other potential rice pests are important sources of food for Northeastern farm families and gathering these products from the rice fields obviously has important implications for plant protection. Many other examples of farmer practices that are in harmony with important farm system interactions exist for Northeast Thailand. Indeed, the intimate relationship of the farmer, his farm and the natural environment is probably the main sustaining force in the agroecosystem.

FARMING SYSTEM BASED SOLUTIONS TO ANNUAL CROP IMPROVEMENT

It would be untrue to state that the improved technologies being developed by NERAD (Pisone, 1987) were all designed around a specific farmer strategy. However, now that an understanding of the more important farmer strategies has been gained, it is possible to understand why some of the technologies are successful and being adopted by farmers while others, although technically and economically sound, are not popular with the farmers. The remainder of this paper will therefore concentrate on describing some of the more promising NERAD-developed technologies in terms of their symbiotic association with important farm system interactions and their effects on the performance of the system as a whole.

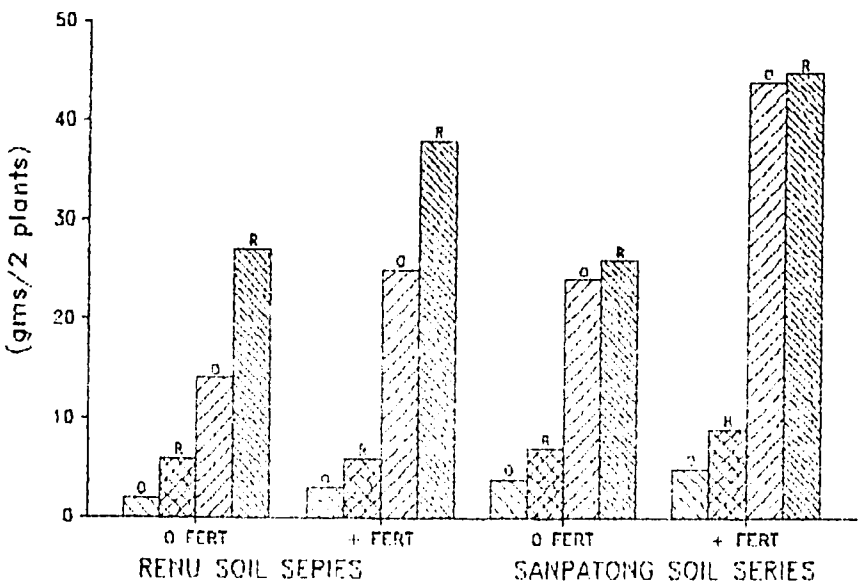
1. <u>Manipulation of the soil-water/soil-nutrient interaction</u>.

Ragland (1986) has demonstrated significant improvements in rice growth (Figure 3) by using soil submergence to produce reduced conditions which enhance nutrient availabilities according to the following equations:

1/ $$Fe(OH)_3 + 3H^+ \longrightarrow Fe^{+2} + 3H_2O$$

2/ $$Fe(H_2PO_4)_3 \longrightarrow Fe^{+2} + 3H_2PO_4$$

Figure 3. Oxidized and reduced soil condition:
Effect on plant growth on Renu and Sanpatong soils



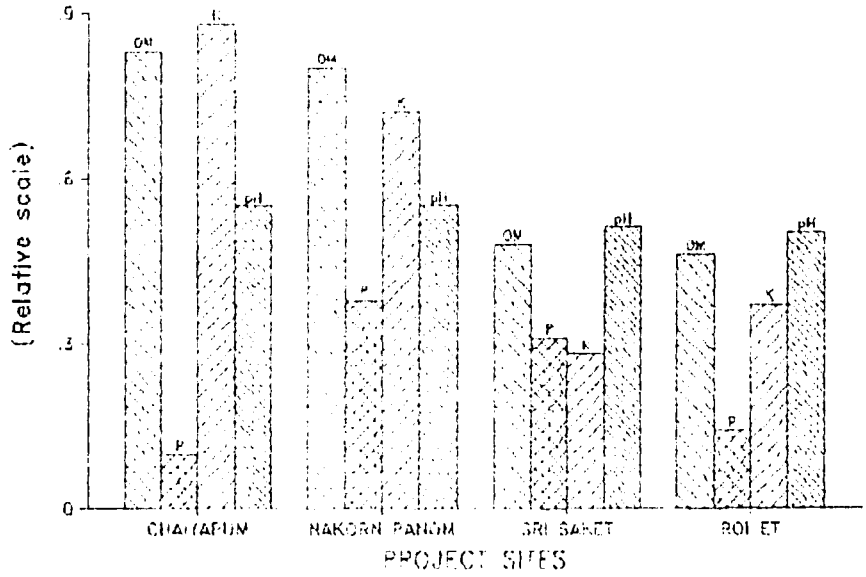
This property was addressed by NERAD with the construction of diversion weirs on the seasonally-dry creeks that criss-cross much of the Northeast and which, during periods of rain, drain away up to 70 per cent of the water that would otherwise remain in the rice fields. The objective of the weirs is to divert the water flowing through these creeks into the rice fields to help keep them submerged in order to maintain the reduced conditions favorable for rice growth.

2. Manipulation of the annual-crop/soil-nutrient interaction.

Both the major annual crops grown in the Northeast are traditionally cultivated year after year with little or no fertilizer application. Both are extremely efficient at removing nutrients from infertile soils: submerged rice due to its ability to grow under reduced, water-logged conditions and cassava by virtue of its physiological response to nutrient stress whereby it maintains leaf nitrogen levels and thus photosynthetic rate at the expense of leaf area index (Cock, 1983). Very little crop residues from either crop are returned to the soil: Cassava due to its high harvest index (Cock, 1983) and rice because most of the straw is removed as cattle feed by the livestock/crop interaction. The result is that traditional annual crop production in the Northeast has been eroding the farm-system-resource-base. This is clearly illustrated at a cross section in time by the current soil fertility levels of the NERAD project sites in order of their longevity in continuous annual cropping since they were opened from primary forest (Figure 4).

Figure 4. Soil fertility levels in the NERAD sites.

---> INCREASING TIME SINCE LAND CLEARED FROM FOREST --->

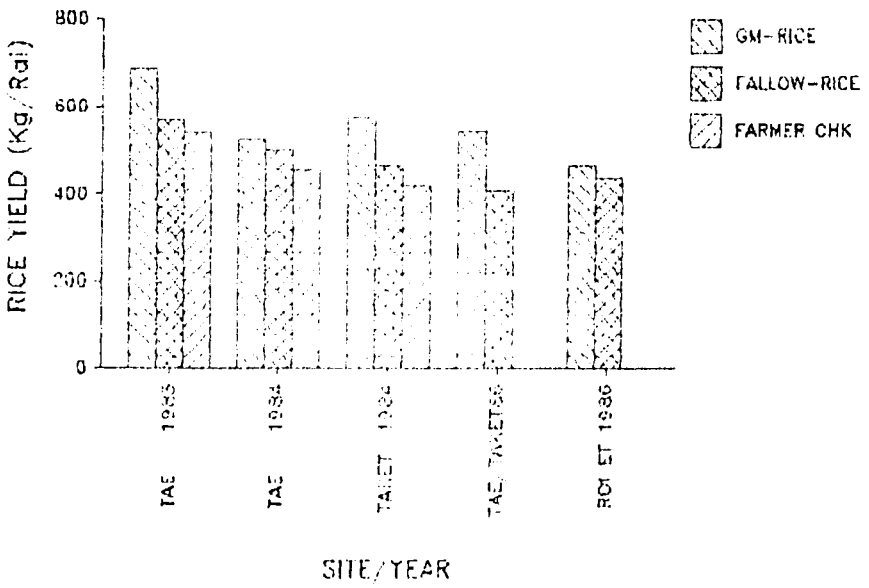


Because of the limited availability of animal manure, the limited production potential for compost and the high cost of chemical fertilizer, attention within NERAD turned to green manuring as the only feasible, low-cost means of manipulating the annual-crop/soil-nutrient interaction to give significant improvements on a large scale. Results of the trials presented in Table 3 and Figure 5 show yield increases due to green manure in the range of only 5 to 20 percent. Farmer interest is very high, however, with significant adoption already occurring in Sri Saket and Roi Et where soil fertility levels have declined the furthest.

Table 3. The effect of green manure on rice yields, NERAD cropping system trials, 1983-86.

SITE/YEAR		GM CROP	REPS	TRIAL	GM-RICE	FALLOW-RICE	FARMER
					Rice yield (Kg/rai)		
TAE	1983	COWPEA	5	ON-FARM	684	569	539
TAE	1984	COWPEA	10	ON-FARM	526	499	455
TAKET	1984	COWPEA	5	ON-FARM	575	464	421
TAE/TAKET	86	CPEA/SES	18	MULTI-L	543	468	N/A
ROI ET	1986	VARIOUS	10	ON-FARM	464	435	N/A

Figure 5. Effect of green manure on rice.
NERAD CROPPING SYSTEM TRIALS, 1983-86.



Green manuring is necessary because soils in the Northeast are generally the poorest in S.E. Asia (Table 4). Unfortunately, this gives rise to the problem that it is often impossible to establish a satisfactory stand of a green manure crop without the use of fertilizer. Once again, a clue to solving this problem can be obtained from a good understanding of traditional farmer strategies. In this case, it may be possible to obtain a satisfactory green manure crop by planting it in the same fields that receive the cattle manure that year under the farmer practice of rotating animal-manure applications previously identified. By this means, it may be possible to permanently sustain or even increase the soil fertility improvement from animal manure by the practice of green manuring.

Table 4. Soil fertility scores for the soils of South East Asia (after Ragland, 1984).

	AREA	RELATIVE SCORE
1.	Sri Lanka, wet and intermediate zone.	-0.33
2.	Sri Lanka, dry zone.	-1.58
3.	Bangledesh, Ganges.	+1.27
4.	Bangledesh.	+0.54
5.	Bangledesh, marginal zone.	+0.57
6.	Bangledesh, Bramaputra.	+0.43
7.	West Malaysia, Kedah-Perlis.	+1.48
8.	West Malaysia, east coast	-0.99
9.	India, Godavari-Krishna.	+1.76
10.	**NORTHEAST THAILAND**	-3.26
11.	Thailand, intermontane area.	-0.93
12.	Thailand, upper central.	-0.30
13.	Thailand, Bangkok plain.	+0.26
14.	Thailand, southern region.	-0.11

Alternatively, it may be possible to obtain adequate green manure crops without fertilizing by careful choice and screening of available species. This work was initiated within NERAD last year by the Department of Land Development with the objective of passing on the promising varieties thus identified to DOA for on-farm testing (Table 5). NERAD's on farm trials also identified a variety of Sesbania (rostrata) obtained from the International Rice Research Institute as having considerable promise as a pre-rice green manure crop for the Northeast due to its ability to grow well and nodulate under acid, saline and water-logged conditions and because of its apparent lack of serious pests in the early vegetative stages. Trials to date would indicate that sesbania is a better green manure crop under wet conditions but cowpea and black bean tend to perform better under dry conditions. Unfotunately, at the time of planting there is no way of predicting the future climatic conditions and hence choice of

Table 5. Results of NERAD green manure screening trials. Nong Kaew, Roi Et, 1986.

CROP MATERIAL	YIELD (Kg/Rai)	
	G.M. CROP	RICE
COWPEA	4352	479
RED COWPEA	1836	446
BLACK BEAN	3728	482
SWORD BEAN	2208	449
NO FIRST CROP	-	435

the most appropriate green manure crop is impossible. In an attempt to overcome this problem, trials this year will include a comparison of sesbania, cowpea and black bean and also a species mixture of all three to test its ability to offset the effect of risk due to the uncertainty of climatic factors.

3. Manipulation of the crop/crop interactions.

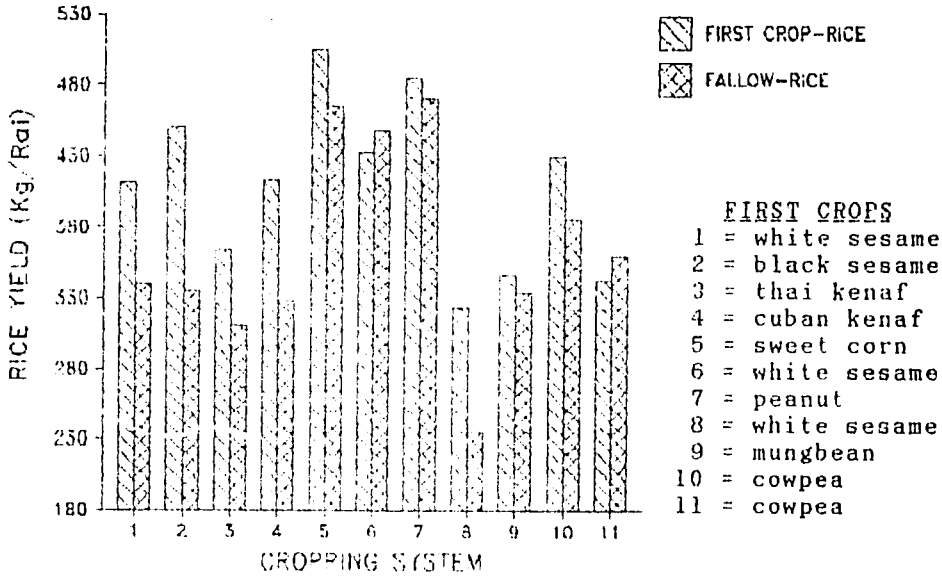
Detrimental interactions between component crops in sequential cropping systems, such as pest and disease build-up, allelopathy, etc. are now well recognized and documented (Trenbath, 1976; Litsinger and Moody, 1976). However, with correct management their negative impact on the farm system can be avoided. Beneficial interactions have also been documented and, with careful manipulation, they have potential for improving the entire system.

Such beneficial interactions have been identified within NERAD's cropping system trials that improve the annual subsistence rice crop, the heart of the northeast farming system. The various pre-rice crops tested in NERAD's cropping system trials over the past 4 years gave somewhat variable results in terms of yield. As shown in Figure 6, however, the yields of the following rice crop were increased in almost every instance by the inclusion of a first crop in the system.

This effect of residual fertility often does not show up on the better buffered, high-clay rice soils of other regions of Thailand. Farmers in the Northeast, however, are well aware of this crop/crop interaction and this may explain the reason why farmers are always willing to participate in pre-rice crop trials even after complete crop failure in previous years. The implication for the researcher is that the current fertilizer recommendations based on component crops are inadequate for cropping systems on the poorly buffered, low CEC, sandy soils of the Northeast. Trials should be conducted to produce recommendations that optimize the performance of the entire system rather than for each individual component.

Figure 6. Residual fertility effects on rice.

NERAD CROPPING SYSTEM TRIALS, 1985



4. Manipulation of crop/fish interactions.

Both on-farm trials and experimental station research conducted by NERAD have shown impressive rice yield increases due to the presence of fish (Figures 7 and 8). Unfortunately, the nature of the interaction is still not properly understood and cannot, therefore, be manipulated to optimise the performance of the entire fish/rice system. Consequently, joint research between the Department of Fisheries (DOF) and the Department of Agriculture (DOA) was initiated last year in order to try and determine the nature of the rice/fish interaction that was responsible for the increased rice yields. Various hypotheses have been advanced to explain the effect including: improved pest and disease control, fewer weeds, soil nutrient effects, the physical effect of fish on the rice plant and its root zone, improved water management and improved cultural care of the rice.

The data obtained from the NERAD trial at the Khon Kaen Rice Station (Table 4) are far from conclusive and will be repeated this year. They do show, however, that the yield increases are due to an effect through grain weight which was significantly different for plots with and without fish and for different fish stocking rates. These results also tend to disprove the theory that increased rice yields are due to the physical presence of the fish stimulating tillering as there are no significant differences for this component of yield.

Figure 7 Effect of fish on rice yield.
FISH IN PADDY, KK RICE STN. 1986.

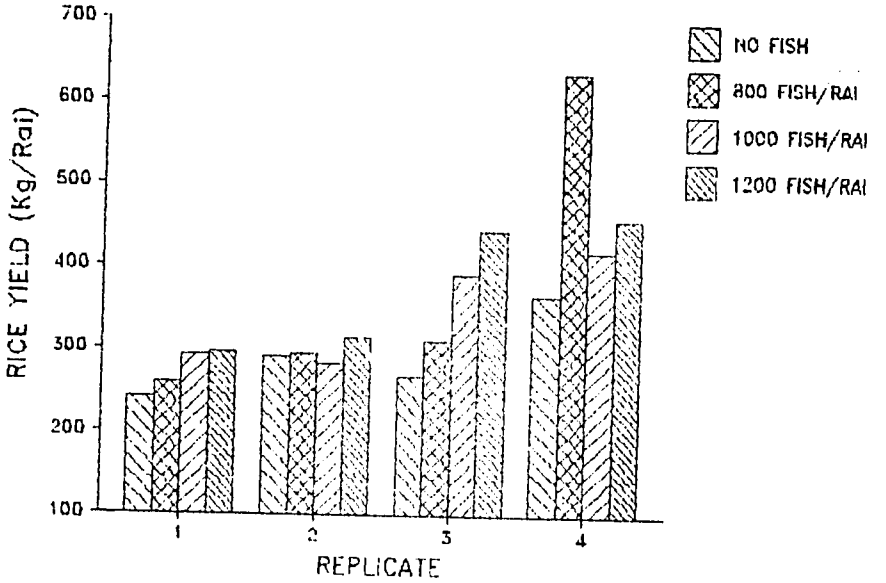


Figure 8. Effect of fish on rice yield.
FISH IN PADDY, SRI SAKET, 1986.

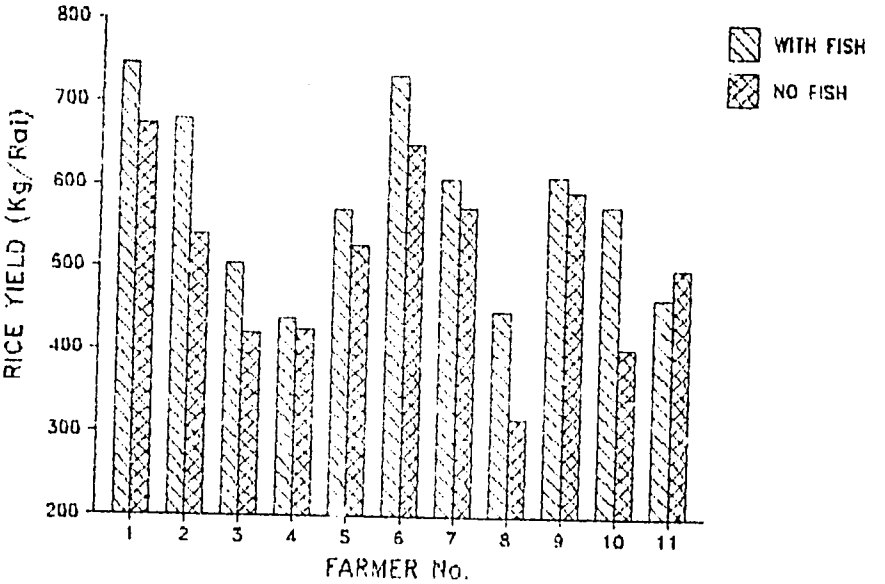


Table 6. The effect of fish on the yield components of rice, joint DOA/DOF fish in the paddy research, Khon Kaen Rice Station, 1986.

COMPONENTS OF YIELD	NUMBER OF FISH RELEASED PER RAI				
	0	800	1000	1200	C.V.(%)
100 GRAIN WT(gm)	2.60	2.66	2.68	2.73	19.9
PLANT HEIGHT(cms)	141	144	144	146	2.6
TILLERS/HILL	7.63	7.40	7.29	8.10	2.4
PANICLES/HILL	6.52	6.20	6.44	6.46	7.9
GRAINS/PANICLE	3630	3801	3653	3954	10.9
% UNFILLED GRAINS	0.76	0.72	0.77	0.77	12.1

Results of the on farm research conducted within NERAD by Officials of the Ubol Rice Center and the Department of Fisheries in Sri Saket are presented in Figures 9, 10 and 11. These trials concentrated on the potential effect of fish on pest, disease and weed control in rice. Once again, no conclusive evidence was obtained but the results do raise a number of interesting hypotheses that will require further testing in future years.

Figure 9. Effect of fish on insect pests.

FISH IN PADDY, SRI SAKET, 1986.

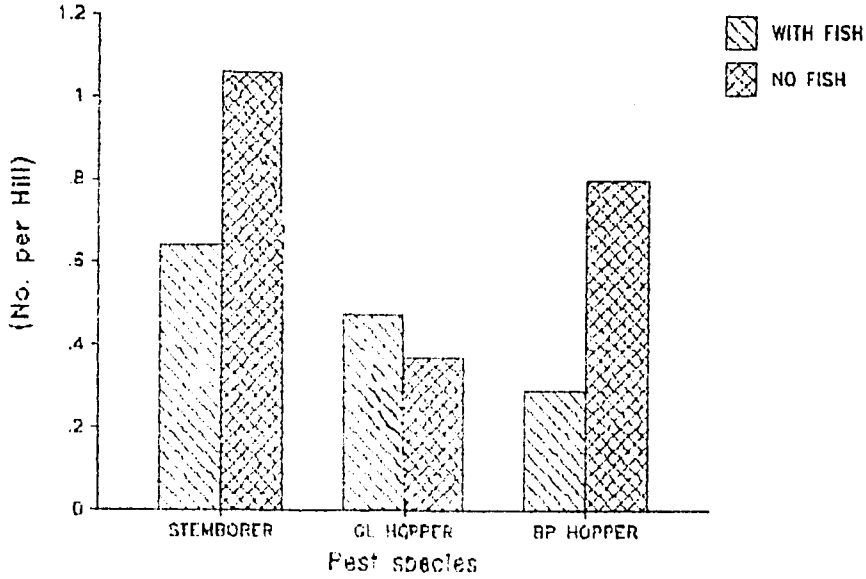


Figure 10. Effect of fish on pathogens.
FISH IN PADDY, SRI SAKET, 1986.

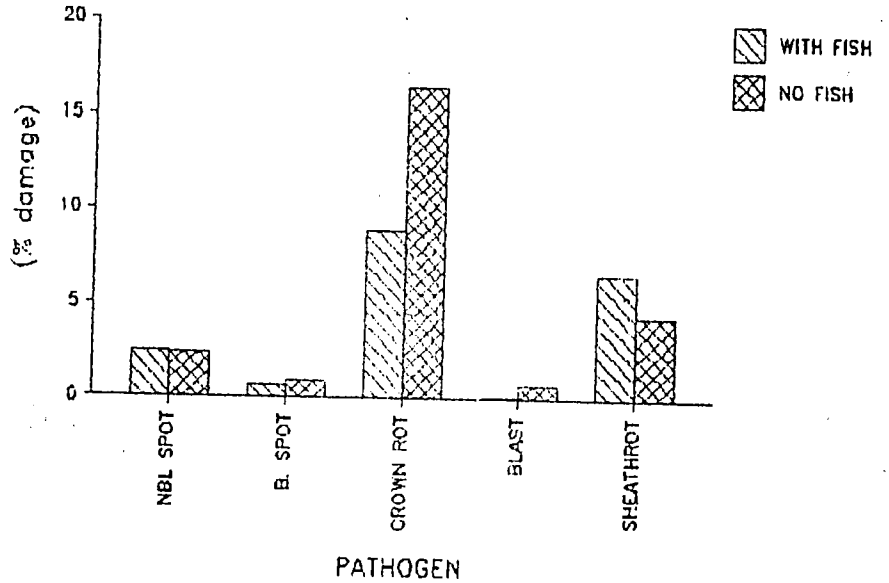
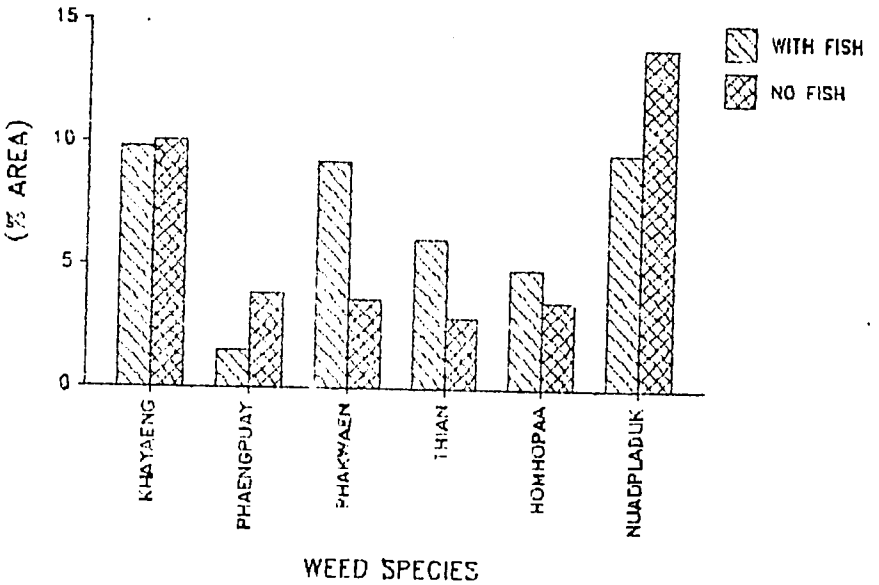


Figure 11. Effect of fish on weeds.
FISH IN PADDY, SRI SAKET, 1986.



The presence of fish appears to have reduced the incidence of some pests, diseases and weed species by up to fifty per cent. The likely effect of this reduction on yield is questionable in some instances such as brown planthopper because of the low pest populations involved. In other instances, such as stemborer and crown rot, where the population reduction was sufficient to significantly effect yield, the mechanism by which fish could have an effect on the pest population is difficult to explain as there are no stages in the life cycle of the pest when it might be susceptible to direct reduction by fish. Possible indirect effects, however, such as changes in pest habitat, host plant attractivity, etc. need further study. Analysis of the mean data presented here is not very satisfactory for this hypothesis-generating research and the data for individual farmer replicates will need to be studied in detail before this coming year's trials can be designed in order to produce results that will help to pinpoint beneficial fish/crop interactions.

CONCLUSIONS

Farming systems, especially those that have evolved under highly stressed conditions, are extremely complex with many interactions occuring between their component parts. Farmers recognise these interactions and manipulate them in order to optimise the performance of the entire farm system. Synergistic, or mutually beneficial interactions between annual crops and other components of the farm system can be identified with the help of an adequate understanding of the farmer strategies currently being followed in that area. The purpose of annual crop based FSRE approaches is to develop appropriate component crop technologies based on an adequate understanding of the important synergistic interactions occurring within the agroecosystem. It is not the role of FSRE, however, to manipulate the individual components of the farm; this is the job of the farmer himself who, alone, has the detailed knowledge of his farm agro-ecosystem sufficient to be able to manipulate its components to optimize the performance of the entire system.

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