Temporal Land Resource Concerns and Farming Systems Research: Chiang Mai Valley, Northern Thailand

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Traditional agricultural research has concentrated primarily on improving *productivity* (average net return to investments of land, labor, capital, and management) with relatively little emphasis on *stability* (variability about mean productivity over time and space) and *sustainability* (long-term productivity). In less developed countries (LDC's), technologies developed using this approach have often been more appropriate to larger, better endowed farmers and those agricultural firms producing for export and less relevant to smaller farmers that can least afford instability and declines in long-term productivity. Dissatisfaction with the results of traditional research strategies to solve problems of small farmers in LDC's has led to the development of more holistic research methodologies. Such approaches, popularly known as farming systems research (FSR), have evolved to strengthen linkages between farmers and researchers and to emphasize research under actual farm conditions.

As agriculture evolves from monocropped traditional practices to double- and triple-cropped farming systems, interactions become more complex. These intensified systems often include time-lags giving rise to the possibility of unforeseen systemic effects which may not exhibit themselves during the initial flush of increased productivity, but may later reduce the potential productivity of the entire system. Conventional research approaches have, in general, failed to address these longer term considerations. FSR encompasses these concerns, as it advocates a wider systems approach, but as currently practiced, particularly at the International Agricultural Research Centers (IARC's), it concentrates on short-term issues and usually does not consider questions of long-term sustainability as well as productivity. Unless a systemic approach capable of longer term concerns is adopted in the research and technology development stage, unforeseen effects may manifest themselves after large-scale farmer adoption leading to widespread and serious damage.

The purpose of this paper is to demonstrate that research tools that concentrate on productivity and ignore stability and sustainability do not serve the needs of small farmers. Field results from Northern Thailand are used to document the necessity to consider long-term as well as short-term economic and environmental impacts.

FARMING SYSTEMS RESEARCH

There are almost as many definitions of FSR as there are advocates (Shaner, Philips, and Schmehl 1982). Recognizing this fact, the Technical Advisory Committee (TAC) of the Consultative Group on International Agricultural Research (CGIAR) attempted to define FSR as part of their review of FSR at the IARC's (CGIAR-TAC 1978). The CGIAR-TAC review team viewed FSR as research (including training) which:

1. is conducted with a recognition of and focus toward the interdependencies and interrelationships that exist among elements of the farm system and between these elements and the farm environment; and

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2. is aimed at enhancing the efficacy of farming systems through the better focusing of agricultural research so as to facilitate the generation and testing of improved technology.

TAC's definition of FSR emphasizes relevance to the objectives of the CGIAR (i.e., to research benefitting the majority of farmers in low-income countries and on commodities representing important sources of food for the developing countries).

When actually viewed in the field, FSR programs at the IARC's are an attempt to develop agricultural production technology that is more relevant to the needs of small farmers. FSR approaches have been encouraged by IARC staff because conventional experiment station type research has too often fostered technologies that were not consistent with the circumstances of small farmers. In contrast, FSR identifies the farming family as the central unit in the research process by directly involving them in the descriptive and testing stages (Gilbert, Norman, and Winch 1980).

Despite the recognized existence of complex systems interactions in FSR, there is a major methodological question of how important systems analysis is to FSR in its applied research context. Based on his extensive study of ongoing FSR programs, Shaner (1983) states that FSR has made little use of analytical tools of systems analysis and, consequently, applied or on-farm research might be a better term for the present approach. Byerlee, Harrington, and Winkelmann (1982) support this statement when they refer to present FSR type research as *on-farm research with a farming systems perspective* (OFR/FSP). Methodological problems increase geometrically as FSR programs become more holistic. These problems, reinforced by the technical crop research mandates of the IARC's and the need to implement FSR programs within the bounds of limited financial and human resources of national programs, have tended to reduce the range of variables actually studied. Thus, FSR researchers usually focus on a few priority problems which offer potential for rapid increases in productivity (Byerlee, Harrington, and Winkelmann 1982).

Zandstra et al. (1979) has mathematically represented this process by developing a functional relationship where livestock growth and crop yield *(Y)* can be considered to be the result of management *(M)* and environment *(E)*, so that

$$Y = f(M, E) \qquad [1]$$

Management *(M)* for FSR includes the arrangement of crops (livestock) in time and space and their associated production practices. Environment *(E)* is composed of such land- and climate-related variables as rainfall availability or irrigation, the soil's textural profile, groundwater levels, and toxicities; day length, solar radiation, and temperature; and cost and availability of such resources as power, labor, cash, and markets, as well as the customs associated with their use (Harwood 1974). Environmental variables considered by a FSR researcher are a result of a decision about the extent to which management is to control environment. To evaluate the relation $Y = f(M, E)$, researchers focus on the interaction between E and M and seek to determine how to vary farming systems to get the best returns from different production environments. Because $Y = f(M, E)$ covers a wide range of production environments, eventually researchers must formulate a statement about the effects of different management practices on the performance of farming systems in a given environment. Thus,

$$Y = f(M \mid E_i) \qquad [2]$$

describes the relationship of M to Y for E_i, a specific environment. Operationally the transfer from equation [1] to equation [2] changes E from a vector of variables to one that imposes constraints (some of which may only be vaguely understood). Interactions that were in terms of E and M in equation [1] are only in terms of M in equation [2] (Zandstra et al. 1981).

This approach, while carefully identifying and combining new technological components to fit the prevailing production environment, fails to recognize that the introduction of these new components may have adverse

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impacts on the environment. In fact, Bernsten and Herdt (1981), explicitly state that FSR omits identification of changes in the agriculture environment stemming from management practices. By assuming E_i is constant, and ignoring the interactions between E and M, FSR does not include a mechanism to determine if production increases resulting from new management practices are, in fact, sustainable over time.

Concern with the interaction of management *(M)* and environment *(E)* and its impact on long-term stability of environmental systems led to the development of ecosystems analysis (Evans 1956). From the study of natural ecosystems it was a relatively short step, conceptually, to the study of agroecosystems (Spedding 1979). By definition an agroecosystem is an ecological system partly modified by man to produce food, fiber, or other agricultural products. The transition from natural ecosystem to agroecosystem, however, involves several significant changes. The system is more clearly defined as man creates the boundaries. Similarly, the number of natural or biological components are reduced and important interactions are modified and regulated by man. Yet, the inclusion of man in the system, including his cultural and economic activities, reintroduces considerable complexity, but of a different nature. It is this rich, new complexity and the type of system properties these generate that makes analysis difficult (Conway 1981).

Agroecosystems tend to occur in a hierarchical arrangement of subsystems where separate crop and livestock enterprises all interact with one another in a complex manner (See Figure 1). Those dynamic interactions bring about properties which are only apparent at a higher level system, namely, the farm. Both interactions within any level of the hierarchy and interactions between factors at different levels in the hierarchy give rise to system properties and must therefore be considered in relation to the performance of the entire system (Craig et al. 1981). The behavior of the system is primarily controlled by a small number of positive and negative feedback loops. Agroecosystem analysis focuses on identifying these critical feedback loops with the assumption that major improvements can be brought about by changes in the key management decisions that influence these processes (Walker et al. 1978). Thus, agroecosystems analysis focuses on the interactions between M and E rather than assuming it away with an assumption of a static E_i.

LAND RESOURCE BASE

FSR programs at the IARC's are designed to adapt, evaluate, and assist in the dissemination of new technologies that will substantially increase net income of farmers. This generally results in synthesizing sequences of crops and fertilizer practices to fit the local environment and the needs of farmers (Zandstra et al. 1981). These types of studies are important but, as presently practiced by FSR researchers, they fail to ensure that the new technologies will not result in long-term negative effects on the environment or even the social system. Considering the farmer and his needs as part of an agroecosystem, such concepts as risk, stability, resilience, and durability become more important than concentrating solely on short-term productivity problems. From a long-term point of particular interest are those properties of the system that result from dynamic interactions among the components such that the system as a whole may react differently from what would be expected from a consideration of individual components. In the following paragraphs these points are illustrated using dynamic reactions in soil that potentially may occur as a result of changes in cropping systems.

Soil Acidity

Soil acidity tends to occur relatively rapidly when tropical soils with low cation exchange capacities are cultivated. The system is complex but in well-aerated soils aluminum toxicities often develop by reaction with other soil constituents. However, in systems where the soils are periodically flooded, reactions with iron and manganese tend to decrease the acidity and bring iron and manganese into solution in their reduced forms. As the soils are flooded, the process has its own feedback as

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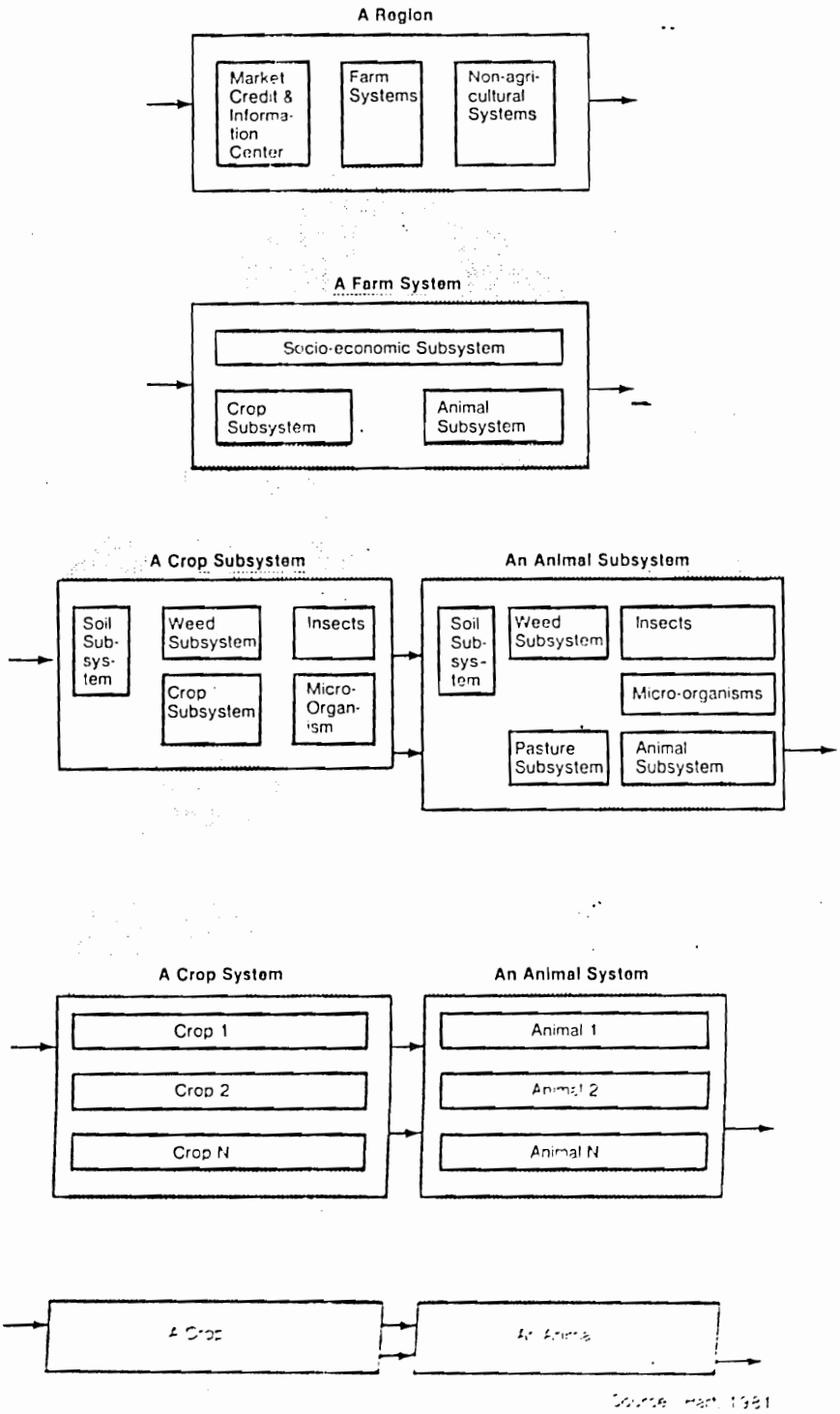

FIGURE 1
HIERARCHICAL RELATIONSHIP BETWEEN AGRICULTURAL SYSTEMS

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the reduced acidity limits the manganese and iron in solution. The general result is that soils that are flooded are usually not particularly acid but rapidly become acid in dry periods. Given this situation, soils subjected to multiple-cropping systems in which one of the crops is flooded paddy rice can be expected to acidify in a stepwise fashion over time, the pH increasing under rice and decreasing under the nonflooded crop (Reuss, 1979).

The level of acidity at which the system stabilizes is a function of soil properties, cropping systems and management practices such as fertilization. As the system acidifies, problems of manganese toxicity, lack of nodulation on legumes, and so on can be expected. Fertilization, particularly with nitrogen fertilizers such as ammonium sulphate, has been demonstrated to intensify the process by inhibiting the ability of soil organisms to nitrify the ammonium (Olson 1972).

ENVIRONMENTAL CHANGES

Data illustrating long-term environmental changes resulting from adoption of intensified farming practices are difficult to obtain and document. This data problem has tended to restrict long-term environmental studies particularly for small farms in LDCs. One case in which a significant amount of long-term information is available is the Chiang Mai Valley in Northern Thailand where the Multiple Cropping Project (MCP) at Chiang Mai University has been studying farming systems since 1968 (Multiple Cropping Project 1976). Research results from this valley can be used to demonstrate that environmental implications of changes in farming systems are important and must be given equal status with attempts to increase productivity.

Since the mid-1960's availability of irrigation water made it feasible to multiple crop large areas of the valley bottom land. Cropping intensity in the valley has increased from less than 120% in 1968 to over 165% in 1980. Using new high-yielding varieties (HYV's) and chemical fertilizer, yields could be doubled in some areas and increased by more than half in almost all areas. Data from farmers' fields in Chiang Mai Valley demonstrates this point (Table 1). With this type of response there seemed to be ample justification for a rapid adoption of new HYV's. Extension personnel and other crop specialists encouraged farmers to adopt these new farming practices although there was little information concerning interactions between these new management practices, including heavy doses of chemical fertilizer, and farmers' cultivation practices on other crops.

TABLE 1
RESPONSES TO NITROGEN FERTILIZERS

	Yields (Metric Tons/ha.)			
	Level of Nitrogen Fertilizer (kg. N/ha)			
Variety	0	30	60	120
Traditional	4.55	4.59	4.73	—
HYV	4.63	—	6.16	6.43

Source: Rerkasem and Gypmantasiri

Long-term data from a set of closely monitored intensively cultivated fields indicate that under multiple-cropped conditions these increases in productivity are not sustainable (Figure 2). After increasing yields from 4 tons/ha. in 1969 to 6.4 tons/ha. in 1971, yields steadily declined so that by 1977 they were again at 1969 levels. The coefficient of variation *(CV)* for the yield data, which has increased from 15% in 1969 to 30% in 1978, dramatically demonstrates that rice production with HYV's in these intensively cropped fields is unstable. This is in spite of consistently high levels of inputs (80–100 kg. Nitrogen/ha.) for the past decade.

This instability appears to be related to rapid changes in soil pH both within the year and across years. Cropping patterns have a strong influence on the changes. From an original pH of about 6.5 in 1968, pH in a sample of intensively cropped fields dropped to less 4.0 after three years of intensive multiple cropping. Since 1971, it has been necessary to use lime on intensively farmed areas in order to keep the soil from becoming too acid but this has not brought yields back up, although it may have prevented further declines. In addition to problems with rice crops, falling

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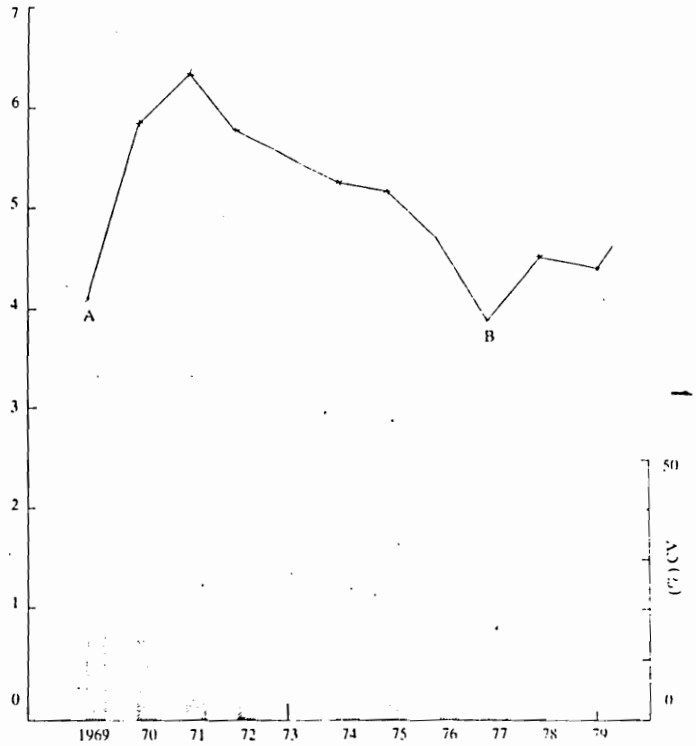

FIGURE 2
RICE YIELD IN INTENSIVE CROPPING SYSTEMS, EACH POINT MEAN FROM 16 FIELDS

yields have also been apparent in other crops. In some areas of the valley, soybean yields have declined from 2 tons/ha. to yields of less than a ton. Yields in some areas have become so poor that farmers have ceased to grow a second crop following rice (Loneragan 1980, Appendix I).

Translating these yield fluctuations into income figures for the valley is complicated by the fact that it is difficult to determine the total area affected. In addition, once farmers realize there is a problem they usually change their crop rotation or leave land fallow. Valleywide surveys were made in 1972–73 by MCP staff and again in the same villages in 1977–78 by MCP staff for the World Bank. Data from these surveys, which included crop cutting, indicate that overall rice yields are increasing, primarily due to cultivation of new land, but that they are less stable (Table 2). With the increasing intensity in the valley, combined with the use of higher levels of fertilizer, it is quite likely that valley rice yields in multiple-cropped fields are in the process of following the same trend as the intensified fields plotted in Figure 2.

To illustrate what these trends mean in terms of income effects, Table 3 includes data from a 1969 representative monocropped field compared to a 1977 representative double-cropped field. Rice yields and production technologies represent an aggregate average drawn from a continuously monitored sample of intensively cropped fields. Soybean yields and production practices are drawn from a subsample of these same fields. Yields of these rice fields are indicated by points A and B, respectively, on Figure 2 while production costs for rice and soybeans are drawn from 1969 and 1977 surveys of intensively cropped areas in the Valley. In intensively cropped fields, by 1977 farmers were forced

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TABLE 2

CHANGES IN AVERAGE RICE YIELDS FROM 22 VILLAGES IN CHIANG MAI VALLEY

	Fertilizer use (kg/ha.)	Average yield (kg/ha.)	Coefficient of variation	No. of cases
1972	20[1]	3063[1]	27%[1]	484[1]
1977	35	3750[2]	41%[2]	385[2]

[1] Tongsiri, Benchaven, Pichit Lertamrab and Alan R. Thodey, p. 169.
[2] World Bank provided data tapes.

to apply much higher fertilizer levels in order to keep yields from declining further. From income calculations presented in Table 3, it is apparent that in current dollars returns to labor and management per year are better with two crops. However, when 1969 prices and 1969 costs are used to calculate 1977 returns, two crops do not provide higher net returns to labor and management. When annual net returns are divided by the days of unpaid family labor and management, the return to family labor and management falls from $2.38 to $1.19 per day. Thus, the two-crop system results in reduced real wages for family labor and management. If, on the other hand, rice yields can be maintained at 6.5 tons/ha., total annual returns (in current dollars) increase to $422/ha. and returns attributable to family labor and management (using 1969 prices) increase to $2.53 per day. The first example illustrates that the sampled farmers in intensive areas are presently working longer hours both in rice and second crop production and are involved in higher level management for lower returns per hour. As off-farm employment opportunities have increased significantly in the valley over the past decade the opportunity cost for labor has risen rapidly. Thus, contrary to claims of crop scientists and extension agents, farmers have not necessarily become better off by multiple cropping. Unfortunately, in some of the intensively cropped areas farmers are now in a situation where they cannot increase yields further; yet, if they reduce fertilizer and other inputs yields will decline rapidly.

POLICY IMPLICATIONS FOR FSR

Traditional agricultural research activities, including those in Northern Thailand, have concentrated on short-term productivity gains. FSR, as currently practiced, utilizes a wider range of information about farm-level production and consumption systems to identify ways to increase production but also tends to concentrate on short-term productivity gains. Agricultural intensification, such as that occurring in the Chiang Mai Valley, entails increased levels of inputs which lead to changes in the environment, including chemical and structural changes in the land resource base. These changes are dynamic and in tropical areas tend to occur faster than in more temperate climates. In the Chiang Mai Valley the immediate need is for agricultural scientists to help farmers develop farming systems, including an appropriate mix of subsistence crops, cash crops (leguminous and nonleguminous) and livestock activities, that are

TABLE 3

NET RETURNS—1969 VS. 1977 ($/ha.)

Year	Yield (kg/ha)		Price $/kg.		Gross return ($/ha)		Costs ($/ha)		Net returns to labor & mgt. ($/ha)		Total ($/ha)
	Rice	Soybean	Rice[1]	Soybean[1]	Rice	Soybean	Rice	Soybean	Rice	Soybean	
1969	4000	—	.055	—	220.00	—	79.00[2]	—	141.00	—	141.00
1977	4000	1316	.092	.27	355.00	245.00	286.00[3]	245.00[3]	82.00	110.00	192.00
			(.055)	(.10)	(132.00)	(106.00)	(125.00)	(106.00)	(95.00)	(26.00)	(121.00)

( ) Converted to 1969 prices.
[1] Wibonpongse, Aree and Earl D. Kellogg.
[2] Thodey, Alan R.
[3] Gypmantasiri, Phrek, et al.

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sustainable over time. Since 1980, this has been the primary objective of MCP researchers at Chiang Mai University. In the broader sense the challenge is for agricultural scientists to anticipate the direction of dynamic changes in resource bases and be prepared with technologies to help farmers as these changes start to restrict output. This argues that instead of playing down the word "systems" in FSR, research scientists must emphasize the dynamics of the interactions occurring in the farm system. Both a system of monitoring dynamic changes and a methodology that allows researchers to predict the direction of those changes is necessary before agricultural researchers can extend new technology packages with confidence. Agroecosystems analysis provides such a tool and, therefore, appears to provide a natural complement to shorter-term FSR programs, especially when long-term sustainability is given equal importance with short-term productivity gains.

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