AGROECOSYSTEM RESEARCH FOR RURAL DEVELOPMENT

Selected papers presented at the
Third SUAN Regional Symposium
on Agroecosystem Research
Chiang Mai, Thailand, 22-24 October 1986

Edited by

Kanok Rerkasem and A. Terry Rambo
with the assistance of
Rongrus Jiranunkrom and Zosima Lameyra

June 1988

Multiple Cropping Centre
Faculty of Agriculture
Chiang Mai University
Chiang Mai, Thailand

and

Southeast Asian Universities Agroecosystem
Network (SUAN)

APPENDIX 3. GUIDELINES FOR WRITING COMPARATIVE CASE STUDIES OF SOUTHEAST ASIAN RURAL ECOSYSTEMS

REPORT OF THE SUAN-EAPI WORKSHOP ON AGROECOSYSTEM ANALYSIS, KHON KAEN UNIVERSITY, KHON KAEN, THAILAND 6-10 JANUARY 1986[1]

Edited by

Gerald G. Marten and A. Terry Rambo

East-West Environment and Policy Institute

SUAN scientists share a broad common perspective on rural ecosystem research: Its key elements are a systems view of rural resource management, integration of the natural and social sciences, and concern with relevance to rural development policymaking. Within this broad perspective, however, each project and even each individual scientist has employed many different research approaches. While such diversity has been healthy in permitting the tailoring of research to the specific needs of the many different situations in which SUAN works, it has made it difficult to relate findings of different groups to a common theoretical understanding of rural ecology.

There is also a consensus that the collection of empirical data has outrun the development of analytical capability in the SUAN groups. A number of potentially useful conceptual models have been suggested, but attempts to test these against empirical data have been limited and there has been little progress in developing improved conceptual frameworks to guide field research. The agroecosystem concept as articulated by Gordon Conway, particularly its specification of four emergent system properties (productivity, stability, sustainability, and equitability), although offering a unifying theme for the network, remains poorly defined. No systematic effort has been made to operationalize its key concepts. The systems model of human ecology proposed by Rambo has provided a basis for integrating social science research into SUAN but likewise has not been fully operationalized. The relationship between human ecology and agroecosystem analysis also remains problematic.

Formulation of a common conceptual framework and the writing of a set of case studies in which available empirical data are related to these conceptual frameworks can advance the state of rural ecosystem analysis. They do this by requiring clearer and more precise definition of key concepts and by revealing gaps in the existing data base and questions that are currently being overlooked.

The major objective is not the writing of definitive case studies, but the opening up of new areas of inquiry and the formulation of more powerful conceptual approaches for future rural ecology research.

A CONCEPTUAL FRAMEWORK FOR RURAL ECOSYSTEM ANALYSIS

Although "agroecosystem" is included in the very name of SUAN, scientists in the network are in reality concerned with a great variety of ecosystems including forests, grasslands, fishponds, and tidal swamps as well as agricultural systems. They are also deeply concerned with human interactions with these biophysical systems, a relationship that is often not included in conventional definitions of the agroecosystem. Therefore, it may be more appropriate to employ the term "rural ecosystem" to describe the subject of the proposed case studies. A rural ecosystem may be most simply defined as a human group and the ecosystem(s) with which it interacts.

There are well developed frameworks or models for describing and analyzing natural ecosystems. It has been possible, with relatively minor modifications, to extend the use of these models to human-managed systems such as agricultural ecosystems. How best to incorporate humans into rural ecosystem analysis is, however, more problematic. Gordon Conway, along with many others trained in the biological sciences, argues for simply treating people as an additional component of the agricultural ecosystem. Some social scientists, notably Vayda and Rappaport, have also considered the human population as simply an additional species in the biological community. Other social scientists, including Richard Norgaard and Terry Rambo, have argued in favor of drawing an analytical distinction between the human social system and the ecosystem. This reflects both the very great complexity of human social organization in comparison with any other species and the fact that human social institutions are rarely directly determined by environmental influences. In this formulation, labelled as the systems model of human ecology, the ecosystem and the social system are considered to be subsystems of the rural ecosystem (see Figure 1 in Percy Sajise's paper in Section I of in this volume).

It is important to recognize that the systems model of human ecology is a heuristic device to encourage thinking about interactions between humans and their environment. Because of its complexity ("everything is linked to everything else") it is not readily translated into an operationally useable model for analysis of actual rural ecosystems. To do so requires specification the most significant variables in the situation being studied. Identification of these variables in each specific situation is one of the major challenges facing the case study writers.

SCOPE OF THE CASE STUDIES

Workshop participants agreed that case studies should focus on the local community or "village" level in the system hierarchy. Interactions between this unit and other units, both neighboring ones at the same hierarchical level and systems at higher and lower levels in the system hierarchy, should be explicitly recognized and described to the maximum extent possible. It was also agreed that the case studies should focus on (1) agroecosystem organization (e.g., structure and functioning), and (2) emergent properties of the agroecosystem and the social system.

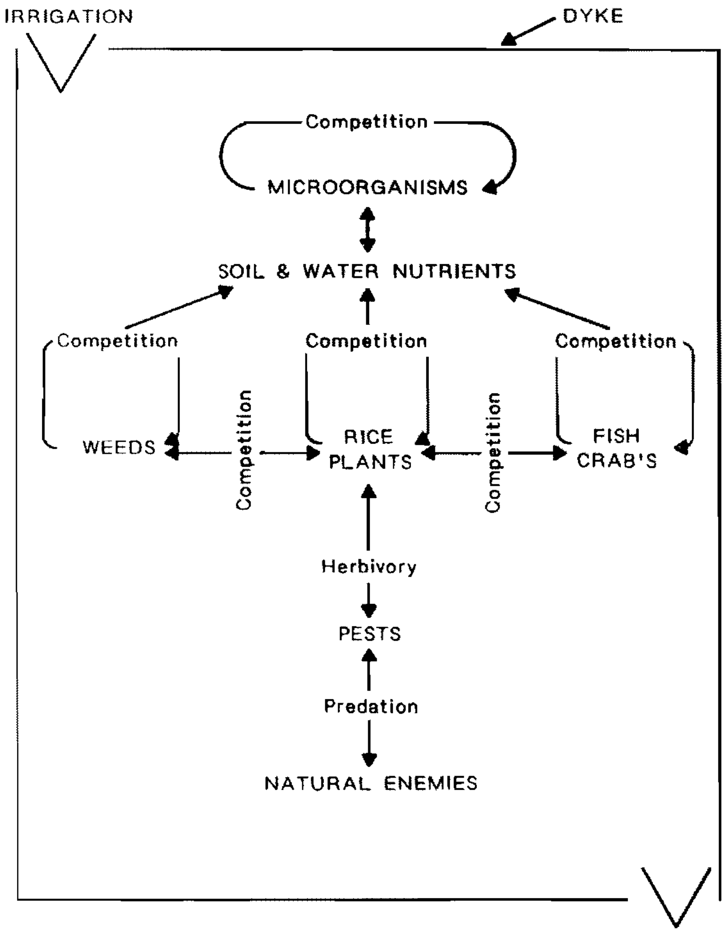
AGROECOSYSTEM ORGANIZATION

Organization refers to the components which make up a system and the relationships between them, what is frequently referred to in ecology texts as ecosystem structure and functioning. A typical agroecosystem is composed of soil, water, crop plants and weeds, livestock, pests, etc. These components interact through exchanges of energy, materials, and information, as, for example, when a cow obtains energy and nutrients by grazing on grass plants. Figure 1 is a diagram of the organization of a rice paddy agroecosystem.

A typical village-level social system in Southeast Asia interacts with several different agricultural and natural ecosystems. The Farming Systems Research Project Village near Khon Kaen, for example, can be divided into lower and upper paddy fields, upland fields, pasture, woodlands, and ponds. There is no commonly accepted term to describe these sub-units of the total rural ecosystem. Both "land use system" and "sub-ecosystem" are used interchangeably in this report.

Delineation of the boundary separating one sub-ecosystem or land use system from another is one of the most problematic aspects of agroecosystem analysis. In Northeastern Thailand, for example, forest, upland fields, pasture, and paddy fields form an interpenetrated mosaic which makes it virtually impossible to clearly demarcate one sub-ecosystem from another. Any attempt to draw sharp boundaries between these land use systems must be arbitrary at best. Sometimes it may appear that the land use system has a distinct and clearly visible physical boundary, as in the case of the dike in the paddy field diagrammed by Conway. In reality, however, isolation of the paddy field from outside influences may be no greater than it is in the case of land use systems having less readily visible physical borders. Soil fertility in the paddy, for example, may be maintained by inflow of sediments eroded from upland areas and carried across the sub-system boundary by irrigation water.

Livestock and other mobile components of the agroecosystem also present a real conceptual problem since they frequently move



Source: Gordon R. Conway. Applying Ecological Concepts to the study of the Intensification of the use of Indonesia's Agro-ecosystems in KEPAS. The Sustainability of Agricultural Intensification in Indonesia Jakarta: Agency for Agricultural Research and Development. 1983:17.

Figure 1. A rice paddy ecosystem

from one sub-ecosystem to another. For purposes of the present case studies it is suggested that livestock be treated as a distinct sub-ecosystem equivalent to paddy fields or forests.

It may prove useful to classify the land use systems more finely. For example, upland fields in North Thailand may contain a cassava crop or a kenaf crop. The functional properties of cassava fields--including such aggregate properties as productivity, stability, and sustainability--can be quite different from kenaf fields. It makes sense, then, to group into a single land use system all upland fields containing crops that function similarly, while assigning to other land use systems those upland fields with crops that function differently. Groupings will depend on the judgement of the analyst.

Groupings will not be obvious for land use systems that include a mixture of crops, because the mixtures can involve so many possible combinations. Homegardens represent an extreme case because all the homegardens in a village contain dozens of crops even though each one of them contains only some of those crops. If some homegardens (e.g., gardens in which annual field crops predominate) function very differently from others (e.g., gardens in which perennials predominate), it may be worthwhile to divide them into two or more land use systems. Even so, the homegardens in each category will still vary considerably, so it may be useful to specify a range of values for their functioning (i.e., inputs and outputs) in addition to the usual averages.

If there is a regular sequence of crops, crop mixtures, or other vegetation on the same field in the course of a year (e.g., double cropping or triple cropping) or in the course of several years (e.g., an alternation between swidden fields and forest fallow), each may be regarded as a land use system. For example, a rice-sesame double cropping sequence can be regarded as two land use systems (rice and sesame), with internal transfers through time between the two land use systems. Rice stubble is an output of the rice land use system and an input to the sesame land use system that follows on the same field. However, for some purposes, particularly when dealing with crop sequences that occur within a single year, it may be desirable to regard the entire sequence (e.g., rice-sesame) as a single land use system.

Describing the Organization of the Local Community Agroeco-System

It is suggested that the local human community be taken as the starting point for definition of the agroecosystem to be described by listing all of the resources used by this community and tracing these outward to their sources. Table 1 presents a hypothetical example of the resource flows into a typical Southeast Asian village. These resource relationships can also be portrayed spatially by drawing simple sketch maps of the community and the landscape units with which it interacts.

After identifying the key sub-systems of the village agroeco-system, the next step is to describe the interactions that occur between these units. A simple method for doing this is to set up a

Table 1. Resource Flows Into a Rural Community Social System

Resource	Source in agroecosystem
rice	paddy field
maize	upland swidden field
eggs	free-ranging fowl
fish	ponds, wet season paddys
firewood	forest
fruit	home gardens, forest
kerosene	market
cash	government works projects

matrix in which the inputs that each sub-system makes to other sub-systems are described (Figure 2).

Initially, such description can be in qualitative terms. Ideally, however, quantitative description of such interactions is desired. The flow of nutrients such as nitrogen can be traced in this way. Such data can also be displayed in the form of an ecosystem flow diagram (Figure 3).

As described above, agroecosystem organization appears static, but in reality it is dynamic, changing from season to season (the annual cycle) and over several years (longer term environmental cycles) and also undergoing evolution as the character of human-environment interactions changes in response to increasing population or adoption of new technologies. Matrices can be prepared representing the state of the agroecosystem at different seasons or under different conditions of human exploitation. For example, in Northeastern Thailand there are such major differences between the wet and dry seasons that one may conceptualize the villagers as interacting with quite different agroecosystems in the course of the annual cycle.

SYSTEM EMERGENT PROPERTIES

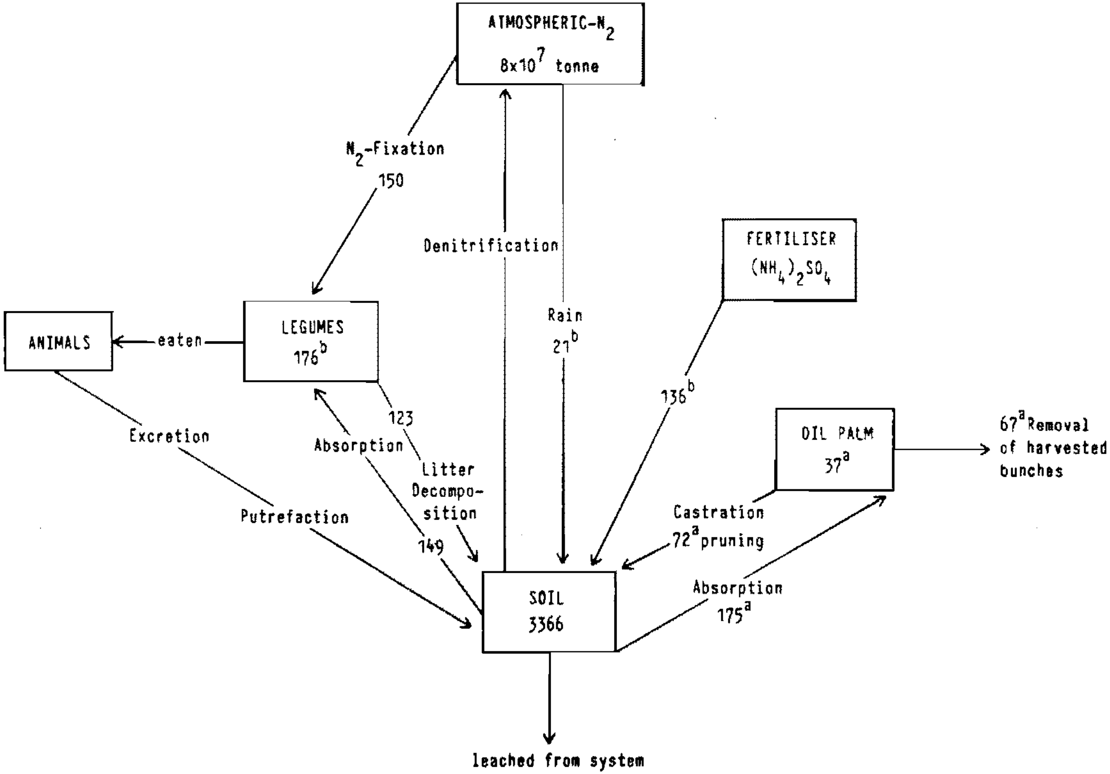
Complex systems are more than simply the sum of all their parts. Their behavior reflects interactions between their multiple components and cannot be predicted from knowledge, however detailed, of their components in isolation. The new behavior which results from the existence of the system are known as emergent properties.

The concept of emergent properties can be applied both to agroecosystems and social systems. SUAN so far has primarily focused on agroecosystem properties but workshop participants recognized the

MATERIAL FLOW AND RELATIONSHIP

From / To	People	Rice field	Livestock	Forest	Fish Pond	External: Market	External: Gov't
People		Fish Rice Crabs Vegetable	Meat	Firewood Leaves Fruits Medicine Games Lumber	Fish Water Veg.	Food, clothing household necessities	Development aid
Rice field	Rainy (H) Labor Dry (L)	Seeds Org. Matter	Labor Manure	Organic matter		Fertilizer, etc.	
Livestock	Rainy (L) Labor Dry (H)	Straw Grass Leaves		Grazeland Fodder	Water	Feeds	Vaccines
Forest			Manure	Org. matter Seeds		Firewood	
Fishpond	Feces	Crop residues, (+) pesticide runoffs (-)					
Market	Labor	Fish Rice Crabs Veg. etc.	Meat	Leaves Fruits Games Lumber Firewood etc.	Fish		
Goverment	Taxes						

Figure 2. Input-output Matrix of Sub-Ecosystems



Source: P. Agamuthu and W.J. Broughton. Nutrient cycling within the developing oil palm-legume ecosystem: Agriculture, Ecosystems and Environment 13(2) 1985:121.

Figure 3. Agroecosystem Flow Diagram

desirability of apying increased attention to social system properties in writing the case studies.

Out of the large number of emergent properties displayed by natural ecosystems, ecologists have commonly focused their attention on productivity, stability, and persistence or sustainability. These were selected because of their relevance to ecological theory. The property of productivity, for example, is usually measured in terms of net primary productivity (NPP) which represents the amount of energy accumulated by green plants (primary producers) in an ecosystem each year. NPP therefore represents the total amount of energy potentially available to support consumer organisms in the ecosystem. Because of theoretical concern with relating energy supplies to the trophic structure of ecosystems, NPP is assigned considerable importance in much ecological research.

Although Gordon Conway applied the labels of productivity, stability and sustainability to agroecosystem properties, it is important to recognize that these are not used in the identical sense to that employed by ecologists concerned with natural ecosystems. Unlike natural systems, agricultural ecosystems are purposive; they are managed by people to achieve socially defined objectives and their emergent properties are defined in terms of their relationship to meeting these objectives. Agroecosystem productivity, for example, is not measured in terms of total biomass, the standard measurement employed in studies of natural ecosystems, but the yield of resources, such as food or fiber, desired by people. Stability is the variation over time, usually from year to year, in the yield of these desired products. Sustainability is not a measurement of the ability of the agroecosystem to persist over time on its own but instead refers to its ability to persist with an acceptable level of human inputs such as labor, fertilizer, or pesticides.

In agroecosystem analysis, therefore, emergent properties are measures of how well the system performs in meeting humanly determined management objectives. The task of agoecosystem researchers is to assess the level of performance of the system in terms of measures of interest to the farmers or other managers. Deciding whether or not such outcomes are good or bad, however, is a matter of values, not science.

Productivity

The unit of analysis for productivity assessment is the land use system, also called "sub-ecosystem" and "subsystem" in the workshop. A land use system consists of one of more kinds of crops, livestock, pasture, and/or trees associated with a parcel of land. It may include crops that are interplanted in the same field (e.g., corn and sweet potatoes) or planted sequentially (e.g., rice followed by soy beans). It also includes all associated vegetation (e.g., weeds), animals, and microorganisms, as well as the management practices necessary to maintain that biological assemblage on the field so it performs as desired.

The basic data for productivity assessment are the inputs and outputs of each land use system. Inputs include not only production inputs (e.g., fertilizer and labor) from outside the agroecosystem under study, but also inputs (e.g., mulch, manure, or animal feed) from natural vegetation systems (e.g., forest) or other land use systems within the same agroecosystem. The latter inputs can be labelled "internal transfers". Correspondingly, outputs include not only products that go to human consumption (e.g., rice or building materials) but also the products that serve as inputs for other land use systems in the same agroecosystem (again, the internal transfers).

The fundamental measures of agroecosystem productivity are the annual outputs of each land use system expressed as weight per unit area (e.g., 1,500 kilograms of rice per hectare or 11,000 kilograms of fuelwood per hectare). Weight units are also appropriate for most inputs except labor, which is measured in hours or man-days. Sometimes it will be necessary to ask farmers about the magnitudes of their inputs and outputs rather than measuring them directly. Sometimes the measurement units will be local volumetric units, rather than weight, requiring conversion from volume to weight.[2]

The outputs of each land use system can be broken down with respect to food, fuel, and fiber (fuel production should also be expressed in caloric terms). In addition, the production of food, and fiber can be broken down with regard to the quantity of products kept for home consumption vs. the quantity sold on the market. The results can be expressed with a bar graph as in Figure 4. "Output profiles" characterize each of the land use systems with regard to average production of food, fuel, and fiber per unit area land. "Output summaries" show how much food, fuel, and fiber the entire village obtains from each of the land use systems. An output summary is calculated by multiplying the output profile by the total land area that the village devotes to each land use system.

If a land use system has more than one kind of output, the outputs can be combined in terms of common units (e.g., economic value or caloric value) to give a single productivity measure for the system as a whole. The same can be done for different kinds of inputs. Such aggregated measures of productivity can provide, by virtue of their common units, a basis for comparing different land use systems. However, because no single productivity measure (including economic measures) can embrace all aspects of agroecosystem productivity that are significant for analysis, the workshop participants suggested several measures as most promising and encouraged each case study group to try others that they consider appropriate. By

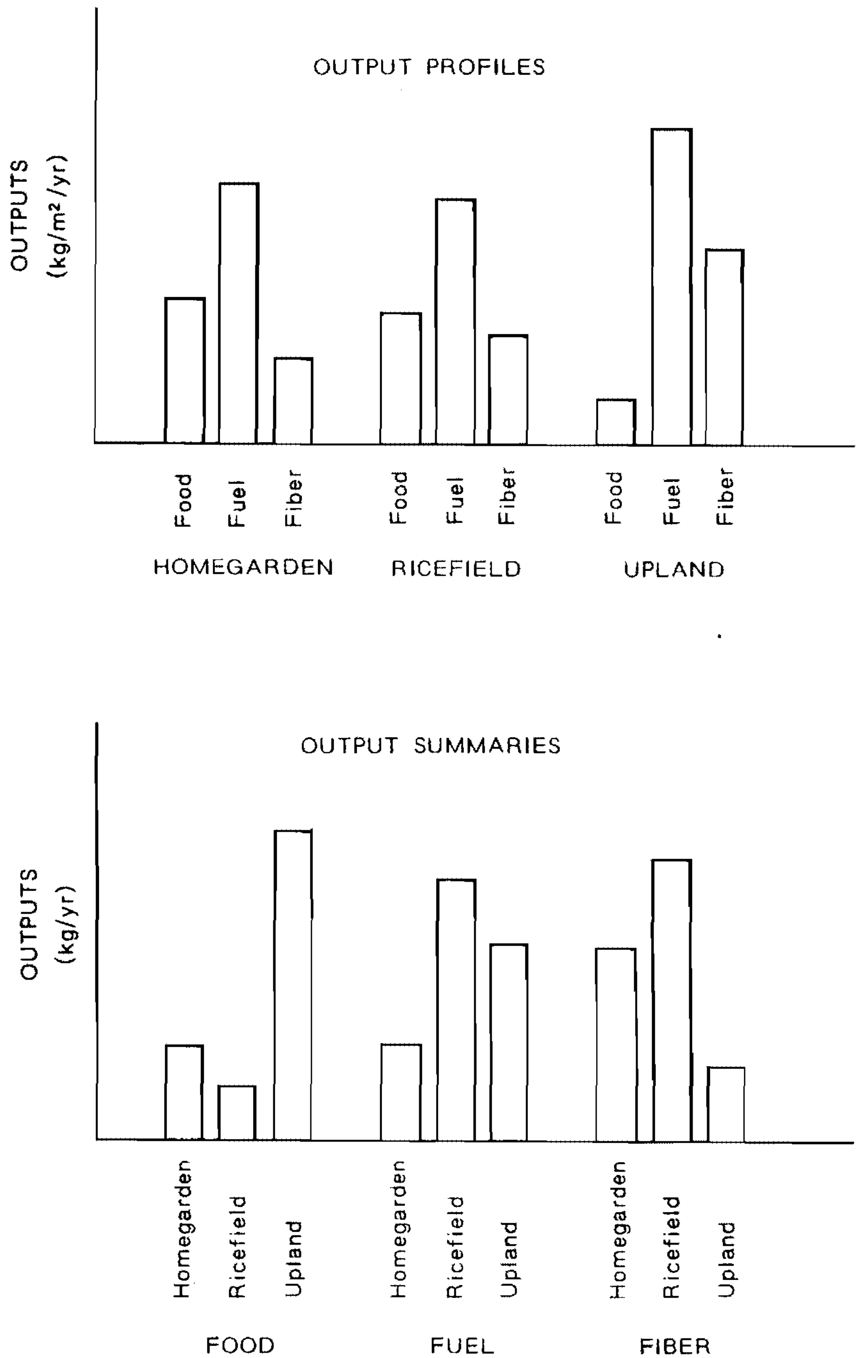


Figure 4. Output Profiles and Output Summaries

working with a variety of measures, we can learn which combination is most useful for our purposes.

The basic economic measure of production suggested by the workshop was gross marginal product (later redefined as net profit), which is the sum of all output values minus the sum of all variable costs. Variable costs include the values of production inputs such as labor and fertilizers while excluding fixed costs such as land rent. However, there was considerable disagreement among workshop participants concerning exactly what should be included in variable costs. We agreed that we are concerned with more than just purchased inputs, but some thought, for example, that family labor inputs should not be included as a variable cost while others thought they should. There was also concern about the fuzziness of estimating the imputed costs of inputs that are not purchased (e.g., family labor, manure from another agriculture system, and crop residues that are used for animal feed). The general opinion of workshop participants was not to decide at this time what should or should not be included in variable costs or how the costs should be estimated. Rather, it was suggested that each case study group should make its economic valuations in the way that makes most sense under the circumstances, taking care to communicate the basis for each valuation.

Productivity can be expressed in economic terms as a ratio of net product to inputs:

$$\text{Land productivity} = \frac{\text{gross marginal product (net profit)}}{\text{unit area of land}}$$

$$\text{Labor productivity} = \frac{\text{gross marginal product (net profit)}}{\text{labor input}}$$

$$\text{Return on input costs} = \frac{\text{gross marginal product (net profit)}}{\text{variable costs}}$$

One or another of these measures of productivity may be more significant in a particular situation, depending upon which inputs are in short supply. For example, if labor is the limiting factor in an agroecosystem where there is an abundance of land, labor productivity may be most significant. Where land is scarce, land productivity may be more significant.

Because some participants considered inputs that require a cash outlay to be economically more significant than other inputs, it was agreed that case study groups may also wish to calculate the following form of return on input costs:

$$\text{Return on cash inputs} = \frac{\text{gross marginal product (net profit)}}{\text{cash expenses for inputs}}$$

In addition to economic evaluation of productivity, the workshop considered a nutritional expression of productivity to be worthwhile. Using food composition tables to convert basic data on the outputs of various foods to outputs of human nutrients is fairly straightforward. Summing the nutrient contents of all food crops produced by a land use system, the result is a nutrient profile for that system. A complete profile should cover calories, protein, vitamin A, vitamin C, thiamine, riboflavin, niacin, calcium, and iron, but it was suggested that each case study might include only nutrients known to be locally critical.

There was also an interest in energy:

$$\text{Energy productivity} = \frac{\text{caloric value of all outputs}}{\text{unit area of land}}$$

$$\text{Energy efficiency} = \frac{\text{caloric value of all outputs}}{\text{caloric value of all inputs}}$$

The Institute of Environmental Sciences, Nanjing, has provided tables of the caloric values of agricultural inputs and outputs for case study groups wishing to do energy conversions.

Stability

Production stability is defined as the constancy of yields or income from harvest to harvest. Because fluctuation is the opposite of stability, stability can be expressed numerically as the reciprocal of the coefficient of variation of yields. For a specified period of time,

$$\text{Stability} = \frac{\text{average yield of all harvests over the time period}}{\text{standard deviation of the yield of all harvests over the time period}}$$

Yields are most conveniently expressed as kilograms or monetary value per hectare per year (or per crop cycle).

Data on yields over a period of time may be based on actual measurements or records of yields, or the data may be based on recall by farmers. Even if farmers cannot recall actual yields, they may have a good idea of the range of yields (i.e., the highest and lowest yields) they have had. Stability can then be expressed as

$$\frac{\text{modal yield}}{\text{range of yields}}$$

where the modal yield is the most common yield and the range of yields is the highest yield minus the lowest yield. Assessing stability from recall may not be highly precise, but it can nonetheless be useful.

Because agroecosystems are hierarchical, we are interested not only in the stability of each individual land use system, but also in its contribution to the stability of the total agroecosystem of which it is a part. It is possible for a land use system's contribution to be in the direction of stability even when it is not itself very constant. For example, one land use system may be able to absorb additional labor and compensate for the production of another land use system that is failing temporarily. If in a particular year there is not enough rainfall for rice in an upper paddy field, the farmer may shift his labor to producing more from his homegarden that year.

Perhaps even more important than a quantitative measure of stability is the identification of sources of instability (i.e., fluctuation). Variations in seed quality, soil moisture (e.g., drought or flooding), cloudiness, pest attacks, and strong winds are examples of ecological fluctuations and other biophysical variations that can lead to fluctuations in yields. Fluctuations in the costs of production inputs (e.g., fertilizer), the selling price of farm produce, provision of farm support services by the government, and availability of labor are examples of social factors that can lead to fluctuation in yields and/or fluctuations in the financial return from agricultural production. All information on sources of instability is worth including, ranging from scientific experiments to speculations by farmers and scientists. However, it is important in each instance to specify the source of information in order to convey its level of reliability.

Finally, we cannot assume that stability is necessarily desirable and instability is necessarily undesirable. Commercial fruit or vegetable farmers, for example, may make an effort to break away from a stable low income by bringing in their harvest at a time when others are not, so they can occasionally enjoy an unusually high financial return on their crop.

Sustainability

Sustainability is the capacity of an agroecosystem to continue functioning on an indefinite basis. The term "persistence" was sometimes used for this property during the workshop. A number of measures of sustainability were suggested, ranging from simple yes/no evaluation (i.e., whether or not a particular system will continue to produce indefinitely at a specified level) to quantitive measures such as the length of time the system can produce at a specified level or the level of inputs required to sustain production. However, as there was no agreement on any particular measure, it was left to each case study group to try out measures that seem most appropriate.

There was general agreement that, at this point in our work, identifying and documenting explicit sources of unsustainability is more important than assessing the degree of sustainability. Soil erosion, loss of soil fertility, increasing soil salinity or acidity, and cumulative pest problems are examples of ecological sources of unsustainability. Examples of social factors are organization problems in irrigation cooperatives or marketing cooperatives, cumulative debt, and insecure land tenure.

Since most case studies do not cover enough time to know for sure whether the land use systems can persist or not, much of the sustainability assessment will have to be by inference. Direct measurements or observations (e.g., soil measurements) can be a starting point for the inference, and it is possible in some instances to project a trend (e.g., soil fertility decline) to draw conclusions on sustainability. However, in many instances the inference will have to be based on theoretical knowledge about social or ecological processes (e.g., soil erosion) and/or empirical experiences under similar conditions elsewhere.

A number of measures of agroecosystem performance--such as the export of mineral nutrients in the harvest, soil loss due to erosion, or decline in nutrient content of the soil (expressed per hectare per year or per unit of produce)--were suggested as being helpful to assess sustainability, but none were measures for which many of the case study groups had detailed data. The use of such measures will therefore have to depend upon the opportunities presented to each group.

It can be particularly difficult to identify and assess sources of unsustainability that are external to the agroecosystem. The appearance of a pesticide-resistant pest biotype, a sudden leap in the price of petroleum (and hence the cost of associated production inputs such as fertilizers), loss of an export market, and a change in government tax structure are examples of this kind of disturbance. (Sustainability in the face of severe and unexpected external disturbances is called resilience). Identification of these disturbances must depend heavily upon the imagination of the analyst, visualizing what might possibly go wrong, how the effects might pass through the agroecosystem, and what the consequences might be. Whether or not a source of unsustainability is external may depend upon the hierarchical level of analysis. Fertilizer prices are external to a village agroecosystem but may be internal at the national level.

In summary, assessing stability and sustainability is not simply a matter of judging agroecosystem performance. Equally important are insights into how stability and sustainability are maintained, i.e., systemic mechanisms that promote stability and sustainability. It is important to document, for example, how farmers deal with various challenges to the stability and sustainability of their agricultural production. This is the kind of information that will best reinforce the ultimate objective of the case studies--to assist farmers in improving the performance of their agriculture.

EMERGENT PROPERTIES OF SOCIAL SYSTEMS

Social scientists who view human societies as holistic systems, rather than as simply aggregates of individuals, have long been concerned with the question of emergent properties. The analysis of solidarity as an emergent property, for example, has been a major concern since Durkheim. The extent of autonomy or independence of developing country societies is a major theme of dependency and "world system" theorists. Inequality as manifested in the stratification of wealth and power is another emergent property of concern to many social scientists.

For purposes of the case studies, our major interest is in the relationships between social system properties and agroecosystem properties. Because they are systems created and managed by people, the performance of agroecosystems is strongly influenced by the emergent properties of the social systems with which they interact. The level of productivity achieved by an irrigated paddy field, for example, can not be predicted solely from knowledge of plant-soil-water interactions. It is also necessary to understand the social arrangements for management of the irrigation network. Rice fields having identical biophysical characteristics can give very different yields depending on the way people manage the supply of irrigation water. Different social systems display very different capabilities to manage water. Conversely, the emergent porperties of social systems are influenced by their relations with agroecosystems. It has been argued, for example, that large-scale water control systems necessitate centralization of decision-making authority in an authoritarian bureaucracy and hence reduce local autonomy. Shifting cultivation, on the hand, appears to favor, perhaps demand, decentralization of decision-making to the community level.

In studying rural ecosystems, therefore, we are concerned not only with the properties of productivity, stability, and sustainability, but also with social system properties that influence management of the agroecosystem and are in turn influenced by it. Of the many possible social system emergent properties of interest (e.g., power, quality of life), the workshop decided to focus on autonomy, solidarity, and equitability.

Autonomy

Autonomy is defined as the extent to which a social system is able to function at a normal level using only resources derived from the agroecosystem over which it has effective management control. An isolated swidden farming community living almost entirely off resources produced within its tribal territory has high autonomy. A modern city state such as Singapore, which is almost 100 percent dependent upon resources imported from beyond its political boundaries, displays very low autonomy.

Autonomy is a multidimensional measure. A system may have high autonomy with regard to some resources and low autonomy with regard to others. In pre-colonial Southest Asia, for example, lowland states were able to exert control over otherwise independent hill tribes by threatening to cut off the trade in salt. More recently, OPEC was able to exert great diplomatic pressure on Western Europe and Japan by threatening their access to oil.

Although a high level of autonomy is often thought to be desirable, particularly by political economists of the dependency theory school, this is not necessarily always so. Bontoc villages in the Cordillera of Luzon, for example, are highly autonomous under normal conditions. In the event of crop failure, however, carefully maintained alliances with other villages allow the transfer of food reserves from rice surplus to rice deficit communties. A truly autonomous Bontoc village might soon become extinct in the face of environmental fluctuations.

Achievement of total autonomy is also an impossible objective for local level communities that are involved in commercial production. The farmers who manage the ecological farm in Nanjing, China, for example, must export virtually all of the meat and fish that they produce in order to obtain cash with which to purchase most of their own food and virtually all of the feed for their livestock.

Measurement of autonomy is simple in theory but extremely complex and difficult in practice. One needs to ascertain both the quantities of exogenous resources that flow into the local system and the significance that these resources have for the normal functioning of the system. A simple quantitative measure of autonomy can be calculated by comparing the total amount of resources used within the agroecosystem to the share of those imported from outside the system. It is important to recognize, however, that small quantities of critical resources may have much more impact on autonomy than what appear to be much larger flows of less strategic goods. The amount of salt that highland tribes obtained from the lowlands in pre-colonial times was small, perhaps no more than a few kilograms per capita each year. Yet because salt was considered absolutely essential for human existence and there were no locally available substitutes, the autonomy of the tribes was severely compromised. Today, farming communities relying on hybrid seed would display similar dependency on external suppliers, even if they do not need other commercial inputs to maintain productivity. Resources which are both essential for continued functioning of the system and difficult or impossible to replace with locally derived substitutes have the greatest impact on autonomy. Anti-malaria medicine represents such a critical resource for many upland forest dwelling communities in Southeast Asia. People can simply not survive without continued suplies of chloroquine and there are no effective indigenous substitutes for this medicine.

A resource need not be physiologically essential for it to be critical to system functioning. Goods upon which a high cultural value is placed, even though not essential for biological survival, may have equal or greater impact on the degree of autonomy. The desire to have tobacco or coffee, or the need to obtain cash to participate in religious pilgrimages or send children to school can also lessen local autonomy. Swidden cultivators on Mt. Makiling studied by the UPLB Upland Hydroecology Program, for example, devoted a large share of their labor not to production of food for their own subsistence but to raising commercial crops to obtain cash needed to send their children to school.

Solidarity

Solidarity is defined as the ability of the social system to make and implement decisions about its agroecosystem management. A community which requires all farmers to plant their crops by a certain date would exemplify high solidarity; but one in which individuals use land or other resources wholly as they please without regard to the consequences of such use to their neighbors displays low solidarity.

Although solidarity is sometimes achieved by means of formal institutions which are explicitly concerned with resource management, e.g., a communal irrigation society which has as one of its recognized roles the allotment of water between individual members' fields, it is perhaps more common for solidarity with regard to resource management to be a latent function of institutions or customs which fill very different overt functions. Coordination of planting time of crops as a consequence of participation in religious rituals is an example of such a latent function. Farmers participate in the rituals because they hold certain religious beliefs and one consequence is that no one plants before the date of the ceremonies.

Solidarity is multidimensional. A community displaying high solidarity with regard to management of one ecosystem component, e.g., water used for irrigation, can display low solidarity with regard to other components, e.g., upland forests.

As is true of all emergent properties, solidarity is a measure of performance and does not imply a value judgement. High solidarity is not always and everywhere a desirable system property. Medieval English villages, for example, displayed high solidarity in their enforcement of standard cropping patterns on all farmers (the "three field system"). It was only after the enclosure movement broke down this communal solidarity that progressive farmers were free to adopt more scientific rotation practices leading to increased productivity.

Measurement of solidarity is extremely difficult. Unlike the case of productivity, a single quantitative indicator (e.g., kilograms of paddy per hectare) is not sufficient; it is necessary to describe social behavior towards all key ecosystem components. The jural framework of rules, regulations, customs, and norms which provide ideal guidelines for management, actual behavior towards the environment, and the processes of making and enforcing management decisions must all be understood and described.

Rules and customs represent an idealized pattern for making and implementing management decisions affecting the ecosystem. The very detailed schedules of water allocation characteristic of many traditional communal irrigation systems offer an example of such ideal guidelines. The existence of such rules does not in itself demonstrate the existence of high solidarity, however. Frequently, communities that lack effective solidarity produce the most elaborate rules and regulations. Many Asian countries, for example, have a multitude of regulations prohibiting cutting of trees in forest reserves, but farmers continue to obtain their firewood from these reserves in defiance of the laws. It is therefore important to know the extent to which individuals and groups within the community actually comply with corporate management decisions.

Understanding the process by which communal decisions about resource management are made is also important. Situations in which decisions are imposed on the community by a few powerful individuals may lead less powerful members to condone covert violations. Alternatively, fear of punishment by the power holders may cause most people to comply with unpopular rules. More democratic decision-making may enjoy a higher degree of voluntary compliance but, when lacking means of enforcement, can also be ignored by individuals willing to risk their neighbors' disapproval.

Some possible indicators of solidarity include:

- community rituals/ceremonies relating to resource management, e.g., ceremonies to mark the opening of the planting sesason
- customary laws regarding resource management
- community-based organizations for managing resources, e.g., communal irrigation societies

- mechanisms for redistributing resources between households

Equitability

Equitability is a measure of how equally the benefits (and costs) of agricultural production are distributed among the practitioners of agriculture. Equitability is a property that pertains to all hierarchical levels from household (i.e., distribution among members of the household) to nation (e.g., equity among regions), but our case studies will focus on equitability at the village level. Although equitability is a value-laden word in the sense that greater equality is usually considered better, we cannot as scientists say that greater equality is necessarily better under all circumstances.

One measure of equitability is a frequency distribution of incomes, which can be displayed on a bar graph. A frequency distribution can be summarized by its coefficient of variation (i.e., standard deviation divided by the average) or by a Gini coefficient.

Perhaps more important than assessing the degree of equitability is identifying the sources of equitability or the lack of it. Much of the equitability of production can be traced to the equitability of inputs for production (e.g., land, water, labor, capital, energy, agricultural chemicals, technology). The same measures for equality of distribution that are applied to production (i.e., frequency distributions, coefficients of variation, and Gini coefficients) can also be applied to equality of inputs.

Going one step further, it is possible to identify the social and biophysical factors that tend to increase or decrease the equitability of agricultural inputs. For example, an abundant supply of physical resources such as land and water can provide equal production opportunities for everyone. Social institutions such as cooperative labor, ritual obligations of the wealthy, obligations of the wealthy to assist others in times of need, and land tenure and inheritance institutions aimed at land redistribution can all lead to greater equality in the distribution of agricultural inputs.

In contrast, advantages of the wealthy and powerful with regard to legal leverage, intimidation, high interest rates, and superior access to government services, markets, and new technologies can lead to less equitability in the distribution of inputs for production. A scarcity of resources like land and water, or variation in their quality, can lead to variation in the equality of opportunities for production. For example, farmers at the lower end of a secondary irrigation channel may not receive the water they need during the dry season, despite the fact that farmers closer to the main channels have an ample supply. To cite another example, some farmers in a landscape with hilly topography may be fortunate enough to have fertile bottomland while others may only have the use of less fertile land on the hillsides, and they may be constrained by susceptibility of the hillside land to erosion.

Our task is to identify how each of the land use systems--as well as the systemic structure of the total village agroecosystem--is coupled with processes promoting equity and inequity. In this way, we can assess their contributions to equitability.

RELATIONSHIPS BETWEEN SYSTEM PROPERTIES

We know that agroecosystem productivity, stability, and sustainability are not independent of one another, but we are not very clear on their interrelationships in the Southeast Asian setting. We know even less about the interrelationships between autonomy, solidarity, and equitability and the ways in which these social system properties relate to ecological properties. In theory, there can be trade-offs (i.e., negative interrelationships) between all of these system properties, as well as mutual reinforcement (i.e., positive interrelationships) between them, but the nature and extent of these is something we can only determine empirically: Our task is to document these interrelationships with an open mind.

The comparative approach is one way to identify interrelationships. By comparing the different land use systems that will be treated in all the case studies, we can see if there is a tendency for the more productive systems to be more or less stable, more or less sustainable, and so on. This approach may generate some hypotheses, but its effectiveness will be limited by the relatively small sample of agroecosystems in our case studies and the numerous uncontrolled factors that will confound comparisons.

Another approach is to look at the processes that connect system properties. Some of the connections are positive. For example, higher productivity may be attained by increasing the harvests in bad years (e.g., irrigation to reduce the impact of drought, or pesticides to reduce the impact of pest attacks), thereby making harvests more even from year to year, increasing stability. Higher productivity can be associated with higher sustainability when a more productive crop provides a more complete cover for soil protection and contributes more crop residues for the maintenance of soil organic matter. Higher productivity can also be associated with higher stability or sustainability if it leads to household savings that give the household the capacity to deal with periodic problems that threaten production. In general, any attributes that increase the adaptive character of an agroecosystem, including "fallbacks", can increase both its stability and sustainability.

There are also many ways these system properties can be negatively associated. For example, higher productivity is associated with lower stability if the higher production is achieved with high-yielding varieties that are more vulnerable to fluctuating environmental stresses such as droughts and pest attacks--or if high yields lead to a glut on the market that depresses prices. Lower stability can lead to higher productivity when farmers follow a stategy of cashing in on occasional periods of unusually high prices for their crops. Higher productivity can be associated with lower sustainability if production is at the expense of soil resources (e.g., by causing erosion, reducing soil organic matter, or exporting soil nutrients), if production is due to heavy inputs leading to major alterations in the ecosystem that eventually undercut production (e.g., irrigation leading to salinization or pesticides leading to the loss of natural enemies and the emergence of secondary pests), or if higher production is a consequence of labor inputs that place a strain on social institutions underlying the organization of agricultural production. Higher stability can be associated with lower sustainability in the face of occasional, severe stresses if, under stable conditions, the agroecosystem (and its inhabitants) cease to exercise their ability to deal with stress (because there is no need to do so) and consequently lose that ability, even though they may eventually need it.

NOTES

1 One of the priority activities identified in the SUAN-EAPI agenda for collaborative work during 1985-87 was the preparation of a set of case studies describing the different types of rural ecosystems being studied by the research groups involved in the Southeast Asian Universities Agroecosystem Network (SUAN). A workshop was held at Khon Kaen University (KKU) 6-10 January 1986 in order to design a common analytic framework for all of the case studies. This paper presents a brief description of the guidelines for case study writing agreed upon by the workshop participants (the Appendix presents a list of participants).

The workshop was co-sponsored by the KKU Farming Systems Project and the East-West Center Environment and Policy Institute (EAPI). It was partially funded by a Ford Foundation grant to EAPI. Dr. Terd Charoenwatana, Director of the KKU Farming Systems Project, and Dr. A. Terry Rambo, Coordinator of the EAPI Human Ecology Program, served as coordinators. Drs. Christopher Gibbs, Terry Grandstaff, and Gerald Marten served as rapporteurs for the working groups that generated the guidelines for writing the case studies. This report is based on their summaries of the discussions and on their notes from the plenary sessions where these suggested guidelines were discussed, modified, and finally accepted by the workshop as a whole. It should be noted that the editors are acting as spokesmen for the consensus reached in workshop plenary sessions and may not be in full consensus reached in workshop plenary sessions and may not be in full agreement as individuals with all of these guidelines.

2 Some participants thought there could be significant erors when estimating the area with which a given measurement of inputs or outputs is associated. This could be particularly so if the land use system occurs in small parcels but does not have clearly defined borders, as can be the case when randomly planted perennials predominate. It was the general opinion, however, that this is an uncertainty that will have to be accepted. A possible solution is to develop a table of equivalents allowing derivation of approximate land area from the volume of seed or other planting materials used, the distance between plants, or other relevant parameters.