J. Asian Farm. Syst. Assoc. 2 (1993): pages 67-87

Farmer Participatory Procedures for Managing and Monitoring Sustainable Farming Systems*

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ABSTRACT. Development imperatives are changing. Maximizing commodity productivity is giving way to sustainable management of natural resources. High external input farming is giving way to low external input farming. With these changes comes the need to help farmers manage the integration of livestock, forestry and aquaculture into crop-based farms. With these changes comes the need to assess the impact of these systems on the environment. Our objective is to devise a farmer participatory method that not only improves farmer management of natural resources, but also monitors the impact of improvements. Farmer participatory methods first identify indigenous categories of natural resources. For each natural resource type, an inventory of crop, vegetable, tree, livestock and fish enterprises is collated. This information is elicited through drawing maps and topographical transects of the resource systems. Bioresource flows between enterprises and resource types are then modeled in farmers' conceptual diagrams, which they display in a prominent place. Farmers monitor and manage resource flows by recording inputs directly onto their conceptual models. At the start and end of a season, the farmers bring their quantified models to a group meeting where lessons are learned "farmer-to-farmer," and researchers collect the data recorded and introduce new techniques to manage natural resources. A rolling design of farmers' experiments in natural resources management is put into place. Our case studies over two seasons with three farmers in the Philippines illustrate how natural resources management can improve. The impact of these improvements in natural resources management is assessed in terms of changes in economic efficiency, biological material recycling, species diversity and resource system capacity. Time series analyses of the four indicators show that dynamism and reversals characterize all farms. Rapid increases and decreases in all indicators occur. Results suggest that high performance in all indicators can occur simultaneously and

* ICLARM Contribution No. 892

that economic loss from crop failure does not jeopardize performance in species diversity and recycling. Although still in its early stages, participating farmers tell of improved resource management and express interest in long-term monitoring. We are confident that these methods will help farmers better manage natural resources. However, time series data on more farms are needed to develop more and better indicators.

While "modern" farming produces food, it does little to alleviate poverty and can even pollute or degrade the environment (Conway and Pretty 1991). Policies that promoted such farming in the quest for food self-sufficiency are now debunked. Food security with care for the environment is the new quest (Conway and Barbier 1990; Pierce et al. 1990). Maximizing commodity productivity is therefore giving way to sustainable management of natural resources. High-external-input, single-enterprise "modern" farming is giving way to low-external-input multi-enterprise integrated farming, particularly, when these external inputs pollute or use nonrenewable resources (Altieri 1987; Lightfoot 1990; Reijntjes et al. 1992). Farming systems research (FSR) must respond with ways to diversify and integrate enterprises like aquaculture, forestry and livestock into crop-based farms. Perhaps more importantly, FSR must demonstrate impact on households, natural resources and the way households manage them.

What natural resources do households have access to? What levels of diversity and integration are needed to rehabilitate or sustain the natural resource base? What balance between inputs and outputs is sustainable? How economically efficient are sustainable farming systems? These are the new questions. Such questions will require us to add new ways of studying farms and working with farmers to the methods of FSR.

In the past, we studied farms as collections of enterprises and attempted to improve the productivity of one or two of them. The new form of study looks not at enterprises but at indigenous categories of natural resources. It goes beyond crop fields to all natural resource types that households utilize in one way or other. We might call this FSR with a natural resource focus. In the past, we used farmer participation to obtain information for better research decisions and on-farm trials. The new form of farmer participation goes beyond data gathering to improve the participating farmers' skills in experimentation and resource management decisionmaking. We might call this farmer-participatory skill building.

Farmers are participating in FSR far more effectively now than they did 10 years ago. Rapid rural appraisal techniques have opened the door to the now almost ubiquitous participatory rural appraisal (Chambers et al. 1989; Lightfoot

1989). Here farmers do the appraisals themselves in the form of self-drawn pictures and diagrams (Lightfoot and Minnick 1991). Similar techniques are used for participatory monitoring and evaluation (Stephens and Putman 1988). These appraisals are still just that - appraisal; farmers appraise a situation, but not much happens to the household as a result. We seek a procedure that will be used by farmers to help them make decisions and devise their own experiments on sustainable ways to use the natural resources that they have access to. This is aligned with what participatory development workers call a learning approach (Korten 1984). At the same time researchers should be able to obtain data as they have always done with participatory research appraisal techniques.

In its early days, FSR as defined by Norman (1978) concentrated on increasing farm yields of particular crops. This form of on-farm research contrasted sharply with earlier multilocation on-farm trials where only the effects of the physical environment were tested. FSR did study the human environment, but with a predetermined focus on the productivity of a particular commodity (Tripp 1991). In the pursuit of greater farmer participation, research shifted to address farmers' problems, but these were very much confined to crop production problems, although links with other components of the on-farm system were studied (Hildebrand 1986). We might call this FSR with a problem focus. The progression in FSR foci is illustrated in Fig. 1. In the spirit of sustainable agriculture we believe our focus on maximizing the economic and biological performance of enterprises must change to the rehabilitation and regeneration of natural resources. We can think of a natural resource focus to FSR, but that will be only part of the story. Our attention to ecological sustainability will need expanding to include the many off-farm and nonfarm activities that make up sources of rural livelihood.

At some time, we will have to think of FSR with a livelihood focus. This work, however, develops our understanding of the natural resource focus which forces researchers to see farms differently. Rather than a collection of independent enterprises conducted on a contiguous plot of privately owned land, the farm becomes a large array of relationships between many different land and water resources which are often non-contiguous and not privately owned. These are better perspectives for those concerned with the sustainability of natural resources and complexity of tropical farming systems. They are also better perspectives for those concerned with the participation of rural people in managing natural resources. Indigenous categories exist for natural resources. This suggests the use of these categories, here termed natural resource types, rather than the individual enterprise, as the appropriate unit around which to structure research on natural resources management.

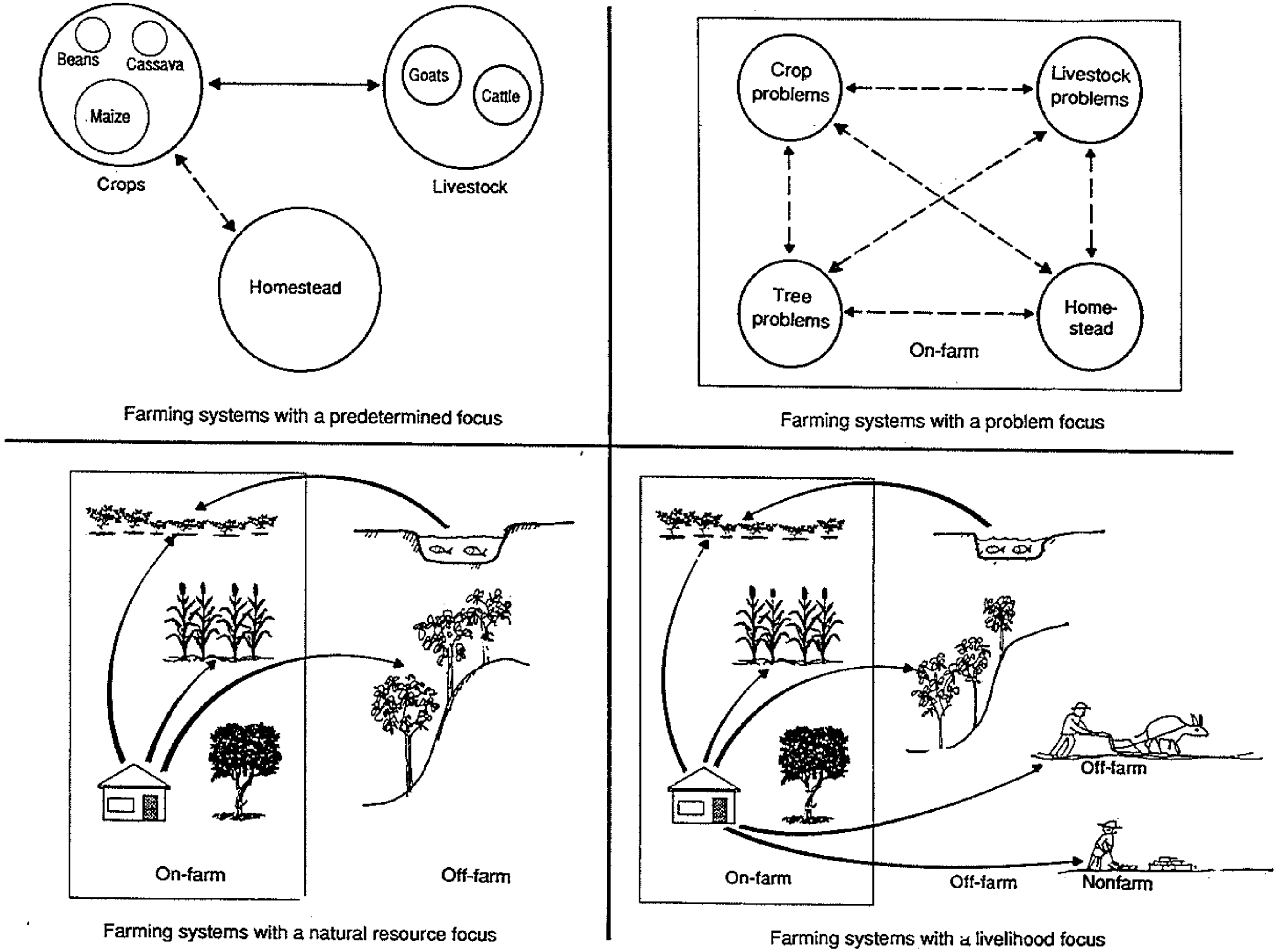


Fig. 1. Progression in farming systems focus.

FARMER PARTICIPATORY PROCEDURES

Elaborated below in four phases are procedures for households to experiment in natural resource management, improve their natural resource management decisionmaking skills, and provide researchers with analytical frameworks for monitoring and assessing impact on households and natural resources.

Phase one: Identification of indigenous natural resource types

Through the drawing of maps and topographical transects, participatory rapid appraisal techniques identify the indigenous natural resource types that the community has access to.

A group of 10-15 farmers, including men and women, is an ideal size to map the indigenous natural resource types in the village. Several teams can be formed to cover large or diverse project areas or target groups. Natural resource types outside the area, live rivers or forests that farmers have access to, are also indicated. A previously prepared base map is used as the focal point of the exercise. It shows the location of the houses, important landscape features (like rivers and hills), and the borders of the village lands. The purpose and use of the mapping are explained, and concepts and methods are clarified with the group. To clarify the natural resource type concept, the participants can be taken to a nearby farm and asked to show the kinds of land and water types found in the farm area.

A walk around the village area follows to identify the natural resource types and their location. As they walk around the area, the participants draw the boundaries of the identified natural resource types on the base map and note down information regarding soil types, water sources, drainage pattern and topography (Fig. 2). They also note the enterprises undertaken for each natural resource type incorporating seasonal variations. After the walk, the participants gather to discuss and verify the information collected and to prepare a final map of the indigenous natural resource types.

From the information gathered, a transect is drawn (Fig. 3). The transect places a topographical sketch of each natural resource type from highest to lowest points in the landscape along the top of a large sheet of paper. This order is not necessarily that in which they occur on the map. Underneath the transect line the following information is recorded for each natural resource type: name, soil type, water sources, crops and vegetables (by season), forage crops (grasses), trees and animals (including fish). Local names, along with English translations, are used for indigenous categories of natural resource types, soil and water types and enterprises. The completed transect is then discussed by the team and corrections made until consensus is reached.

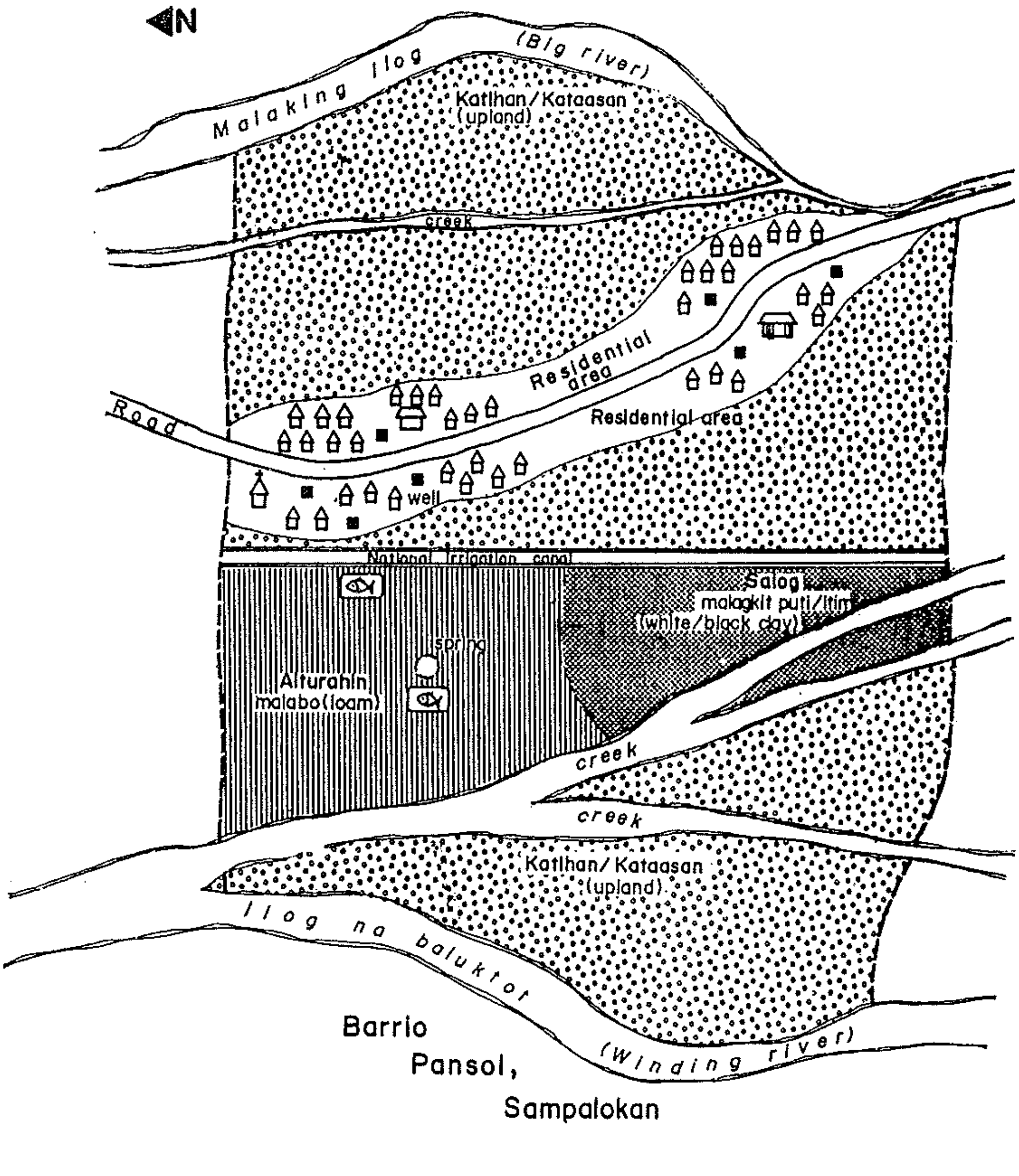


Fig. 2. Natural resource map of Pook Paliparan, Dasmariñas, Cavite, Philippines.

Having completed the map and transect with the group, it is desirable to verify the information with other representatives of the community. In our experience it is often the first time that the community sees their natural resources in this way. This new perspective also provides researchers with a good grasp of the available natural resources and farming systems practiced.

Phase two: Modeling bioresource flows

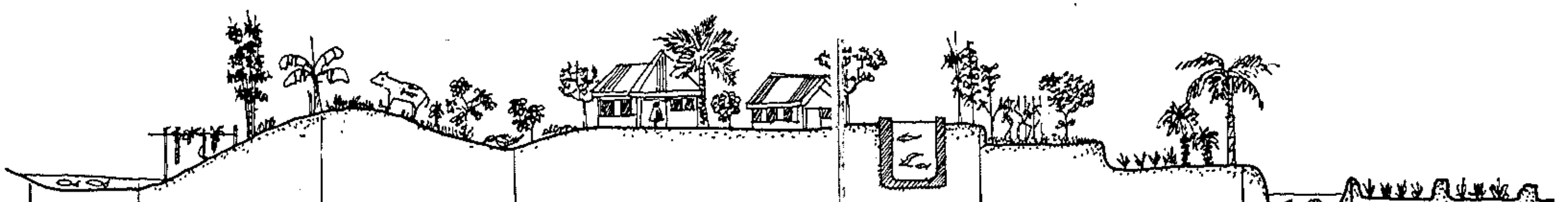
Participatory workshops explore the potential of farmer-drawn conceptual models of bioresource flows for households to improve resource management decisionmaking and experimenting skills. The actual drawing is preceded by visits to selected participant farms to establish rapport among participants and refresh their knowledge of natural resource types, farm enterprises and resource flows.

At the workshop, each participant sketches the natural resource types and enterprises on large sheets of paper. Included in the drawings are systems beyond the farm that they have access to. Sketches of the natural resource types should be topographical cross sections of the landscape as shown in Fig. 4. Natural resource type descriptions include information on soil types and water resources used. Special attention is needed to ensure that common property resources are not left out of the picture.

Individual enterprises within each natural resource type are identified by drawing symbols on top of the natural resource type cross section. Indigenous terms with English translations are added for names of crops, vegetables, trees, forage crops and animals.

Lastly, the participants draw arrows between enterprises and natural resource types to show the flow of farm-generated biological materials, e.g., cow manure used as a feed/fertilizer input in the fishpond. The arrows are completed with the name and amount of material and the frequency of the flow. Quantities are given in local terms and units (such as bucketfuls or bundles) or conventional units according to individual preferences. In most cases the participants are naturally inclined to include the flow of products from the fields to the household in their diagrams. Inputs to and outputs from the house, apart from biological by-products such as kitchen waste, cooking ash and night soil, are not flows because crop produce being consumed are considered as materials output. External inputs to fields like inorganic fertilizer are not flows either. The completed models now form the basis of brainstorming sessions between farmers and researchers. Participants elaborate on how different enterprises and natural resources support and regenerate each other and how cash is saved when by-products are used to

Fig. 3. Village transect of natural resource type, Pook Paliparan, Dasmariñas, Cavite, Philippines.



Resource system	Creek	Creek banks	Upland (katihan) (kataasan)	Residential area (Bahayan)	National irrigation canal	Lowland (alturahin) (tubigan)	Fishpond (palaisdaan)	Lowland (tubigan) (salog)
Soil type		Clay loam (malabo/malagkit)	White/black clay (malagkit puti/itim) rocky (mabato) loam (malabo)	Loam (malabo)/white/black clay (malagkit puti/itim)		Loam (malabo)	Clay loam (malagkit)	White/black clay (malagkit puti/itim)
Water resource		Wet season rainfall, dry season manual irrigation using creek water	Rainfall	Artesian wells		Wet season rainfall, dry season irrigation	(spring)	Wet season rainfall, dry season irrigation
Crops		Wet season: maize (mais)	Wet season: sugar cane upland rice (palay)			Wet season: rice (palay)		Wet season: rice (palay)
Vegetables			Wet season: Bitter gourd (ampalaya) string beans (sitao) lady's finger (okra) eggplant (talong) radish (labanos) tomato (kamatis) pepper (sili)	Various vegetables including lady's finger (okra) spanishgourd (patola) horse radish (malunggay) wing beans (kalamismis) passion fruit (masa flora) grapes (ubas)		Dry season: Bitter gourd (ampalaya) string beans (sitao) lady's finger (okra) spongegourd (upo), pumpkin (kalabasa), water melon (pakwan) tomato (kamatis), pepper (sili) chinese cabbage (pechay) mungbean (munggo) cassava (kamoteng kahoy) sweet potato (kamote)		Dry season: bitter gourd (ampalaya) string beans (sitao) lady's finger (okra)
Forage crops		Grazeland: wild grass (talahib) guinea grass (cogon) gliricidea (kakawate)	Napier grass and weeds				Water hyacinth (kangkong) Azolla (azolla)	
Trees		Bamboo (kawayan) banana (saging) gliricidia (kakawate) kadios	Mango (manga) tamarind (sampalok) star apple (kaimito) sineguelas	Acacia manguim, santol, guava (bayabas), mango (manga), coconut (niyog) soursop (guyabano), jackfruit (langka) star apple (kaimito), banana (saging), gliricidia (kakawate), leucaena (ipil-ipil), bamboo (kawayan), papaya		Acacia mangium, santol, guava (bayabas), mango (manga),citrus (kalamansi), coconut (niyog), jackfruit (langka), star apple (kaimito), banana (saging), gliricidia (kakawate), leucaena (ipil-ipil), bamboo (kawayan), papaya *Sesbania rostrata*, tamarind (sampalok)		
Animals	Catfish (hito) mudfish (dalag) tilapia, golden snail (kuhol) frog (palaka) monitor lizard (bayawak)	Dry season grazing: cow (baka) goat (kambing) water buffalo (kalabaw), pig (baboy)	Duck (itik), chicken (manok), turkey (pabo) pig (baboy), goat (kambing), cow (baka) water buffalo (kalabaw)	Duck (itik), chicken (manok), turkey (pabo) pig (baboy), goat (kambing), cow (baka) water buffalo (kalabaw)	Mudfish(dalag) catfish (hito) tilapia golden snail (kuhol) bullfrog (palaka)	Dry season grazing: Water buffalo (kalabaw) pig (baboy)	Duck (itik) tilapia carp (carpa) mudfish (dalag) catfish (hito) golden snail (kuhol) bullfrog (palaka)	

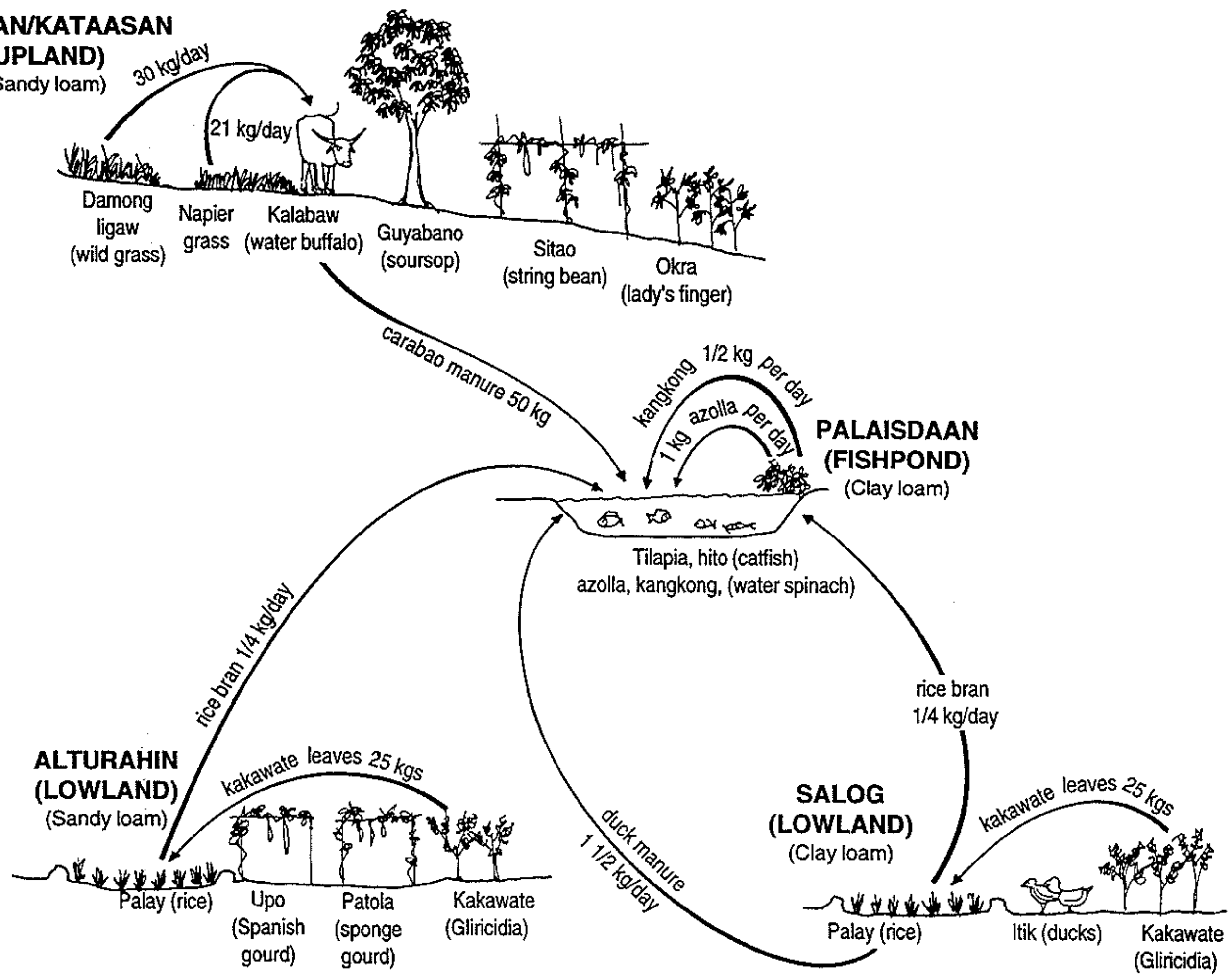


Fig. 4. Bioresource flow model of Farmer 1, wet season, June-November, Cavite, Philippines.

substitute external inputs. Farmers exchange technical ideas about how new flows and new enterprises can be integrated into ongoing farming systems. Ideas for experiments in better natural resource management emerge not only from farmers but from researchers as well. All participants are encouraged to draw on the model the future bioresource flows, enterprises and resource systems improvements they would like to experiment with on their farms.

Phase three: Monitoring farmers' experiments in natural resources management

Monitoring is preceded by visits to farmers who have decided to experiment with some of the ideas for regenerating natural resources, and integrating new enterprises and bioresource flows emerging from the brainstorming session. As with most on-farm experiments, but to a lesser degree, researchers and extensionists assist farmers to obtain the necessary inputs. These visits are also used to help farmers prepare their monitoring diagrams.

A monitoring diagram (Fig. 5) consists of a transect of all the natural resource types utilized on which planned bioresource flows and enterprises are drawn. The space underneath the transect is developed into a matrix for recording the following data: external material inputs (cash and non-cash) derived from outside the farm, family labor, hired labor expenses (cash and non-cash), rents and fees (paid in cash and kind), primary farm produce (sold as well as those consumed at home, given away, stored or used for in-kind payment), and farm by-products (sold and others).

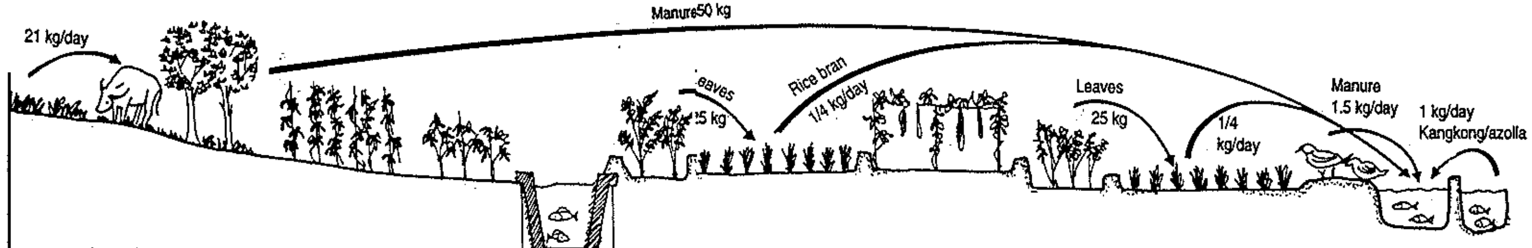
Information on all inputs and outputs is gathered and quantified, using both cash and weight equivalents.

A detailed activity breakdown for each enterprise (e.g., hours spent plowing, planting, weeding, spraying, etc.) as would be required in a farm management survey is unnecessary for the level of impact assessment intended here. Aggregate figures on labor inputs, material inputs and produce suffice for our purpose.

Obtaining monetary values on internal flows can be tricky, but there are ways to handle the problem. If an identical product can be purchased locally at the market, estimating the value is straightforward. Where this is not so, the value of an equivalent input, which could replace flow, can be used as a guide.

Obtaining data on family labor is often difficult, particularly on farms characterized by a large array and diversity of integrated enterprises and natural resource types. In these cases the farmer cannot easily estimate the time allocated to each individual enterprise. The household is normally able to give rough estimates on proportions of time spent on the various enterprises.

Fig. 5. Farm transect of Farmer 1, wet season, June-November 1991, Cavite, Philippines:



Resource system name Soil type	KATIHAN/KATAASAN (UPLAND) Malabo (Sandy loam)						ALTURAHIN (LOWLAND) Malabo (Sandy loam)			SALOG (LOWLAND) Malagkit (Clay loam)		PALAISDAAN (FISHPOND) Lagkit (Clay)	
Enterprise name and area	Napier grass 50 m²	Carabao (2)	Soursup trees (10)	Sitao (String bean) (400 m²)	Okra (Lady's finger) 400 m²	Irrig. Canal (Nat. Irrig. Authority)	Kakawate (Gliricidia) 0.25 ha	Palay (rice) 4,000 m²	Upo + patola (bottle gourd + sponge gourd) 200 m² + 200 m²	Kakawate (Gliricidia) 0.25 ha	Palay (rice) 6,000 m²	Itik (ducks) 16	Tilapia + hito (catfish) 450 m²
External material				Asudrin (1 bottle) 0.3L = P90	Pesticide (bottle) 0.3L = P90			Inorg. fertilizer : (60 kg) = P306 Pesticide: 0.4L = P120 Seeds : (40 kg) = P180			Inorg. fertilizer: (09 kg) = P594 Pesticide: 0.4l = P180 Seeds: (60 kg) = P270		Inorg. fertilizer: 2 kg = P16
Family labor (₱)*		1 hour/day P50/day	Harvest: 3hrs. = P2,625	5.375 person-days = P402.50					All activities 4.875 person-days = P446.25				Feeding 5.625 person-days = P393.75
Hired labor (₱)*								Planting = P300 (6 persons) Food = P60 land prep. = P280 (contract)			Planting = P450 (6 persons) Food = P90 land prep. = P420 (contract)	Cleaning/feeding 5.625 person-days P393.75	
Primary output sold			30 kg = P210	204 kg (102 bundles) (P15-20 per bundle) = P1,777	61 bundles = P1,600			4.4 cavan (220 kg) =P990	Upo: 244 kg = P1,345 Patola: 181 pcs = P904		6.6 cavans = (300 kg) = P1,485	60 eggs = P165	tilapia: 4 kg = P120
Primary output others					4 bundles = P44		75 trellis for firewood = P25	31.6 cavans (1,580 kg) = P7,110	Upo: 22 pcs = P110 Patola: 40 pcs = P200	75 trellis for firewood = P25	47.4 cavans (2,370 kg) = P10,665 40 eggs = P110		tilapia: 16 kg = P440
By-products sold													
By-products others	3,780 kg = P1,890 Manure 50 kg = P25						Gliricidia leaves 25 kg = P12.5 Gliricidea branches 5 kg = P25	Rice bran: 90 kg = P490		Gliricidia leaves 25 kg = P12.5 Gliricidea branches 5 kg = P25		Duck manure 270 kg = P135	
Rents and fees													

* ₱27 = US$1

Recording of hired labor does not normally constitute a problem as this, in most cases, is associated with an actual cash cost and thus is relatively easy to recall.

The monitoring diagram is displayed in a central place, visible to all household members during the period of monitoring. This does not mean that the household needs to record every day; aggregate figures will suffice. Recording can be done in an ad hoc fashion that the household feels comfortable with.

Time frames of data recording can be monthly, seasonal or annual. From our initial experiences the following scheme has proved useful: brainstorming workshop and initial visits at the beginning of or just prior to the start of the experimental season; two to three follow-up visits to individual households during the season to solve any practical and conceptual problems, and to assist with the acquisition of inputs and implementation of new technologies; end-of-season workshop to gather data and share experiences and ideas generated.

Farmers find these end-of-season workshops useful; they learn not only many new ideas but also ways to make such ideas fit into their particular farm system. Again, meetings over the bioresource flow models provide a medium for researchers to introduce new ideas for another round of experimentation. One can describe this as a rolling experimental design in farming system transformation that leads to more sustainable farming systems.

Phase four: Assessing the impact on farming systems sustainability

This assessment illustrates our technique and some analytical possibilities only because data from three farmers are insufficient for any conclusions to be made about impact.

Selecting appropriate indicators for quantifying sustainability is not a simple task. Sustainability is commonly associated with a range of themes and parameters including complexity, structural heterogeneity, nutrient recycling, energy flow and storage, resilience, diversity, resource use efficiency, stability, productivity, equity (Conway 1987, 1991; Rerkasem 1989; Harrington 1991; Giampietro et al. 1992). Given this array, choosing where to start is not simple.

Some vital parameters of social and institutional nature are extremely hard to measure. Gender equity, for instance, needs fundamental research before easy-to-measure parameters will be available to farming systems people.

In the end, our focus on natural resources and common sense of the we-cannot-do-everything type prevailed and our working set of "sustainability indicators" became: economic efficiency, bioresource recycling, species diversity and natural resource capacity. Economic efficiency is defined as net farm income or profit. Bioresource recycling is measured by the number of farm-generated bioresource flows as identified on the bioresource flow diagram. Species diversity is measured by the number of individual species cultivated or otherwise utilized. Natural resource capacity is derived from dividing biomass output (in kg/ha) from all natural resource types by the number of resource systems. At present the definitions and units of measurements (numbers, cash values) of the selected sustainability indicators are rather crude. More elaborate and appropriate interpretations and definitions of the various indicators will develop as more data are collected and methodologies refined.

Our three participating farmers were cooperators in the International Institute of Rural Reconstruction's (IIRR) promotion of small pondwater holding and fish culture, and rice-fish culture. IIRR had introduced these technologies in 1989/90. We started our monitoring with them in late 1991 and have completed two seasons: the 1991 wet season and 1992 dry season (ICLARM 1992). To generate the needed time series data, we undertook retrospective interviews for the 1989 wet season, 1990 dry and wet seasons, and 1991 dry season. We also asked the farmers to predict the outcomes of the ongoing 1992 wet season and share with us their plans and expectations for the 1993 dry season. All three farmers were able to recall their experiences back to 1989 with the usual unreliability that surrounds such exercises. Looking ahead was a little harder because of the uncertainties of land tenure and the market pressures of nearby settlements, rapid urban development, and the knowledge that their lands are soon to be purchased for industrial development.

Over the whole period, there has been considerable change in the farming systems. Water resources have been improved through impounding and improving rice paddies. New enterprises have been added and new bioresource flows have been made. Given that the bioresource flow modeling technique was introduced late in the period, a causal link cannot be established. Indeed, over the monitoring period, both increases and decreases in diversity, recycling, economic efficiency and natural resource capacity occurred. The changes in sustainability indicators over the total period for each farmer are shown in Figs. 6, 7 and 8.

Earlier caveats permit only a few statements to be safely made about these results. Perhaps the safest observation is that dynamism and reversals characterize all the three farm graphs — dynamism in terms of rapid increases and equally rapid decreases in all sustainability indicators. On all farms we see increased diversity and recycling as water resources are improved to permit the culture of fish and aquatic plants, and more feeds go to the animals, including fish, and more manure flows to vegetables. But both indicators go down too. Farmers 1 and 3 have turned their farms into predominantly piggery operations in response to

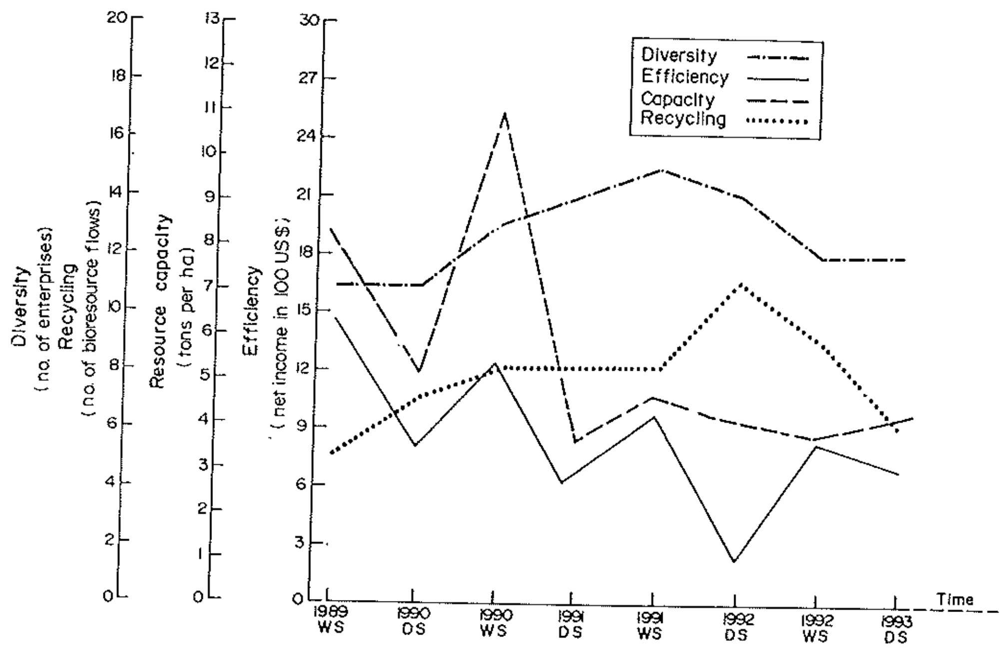


Fig.6. Farming systems sustainability indicators for Farmer 1, Cavite, Philippines. WS = Wet season, DS = Dry season.

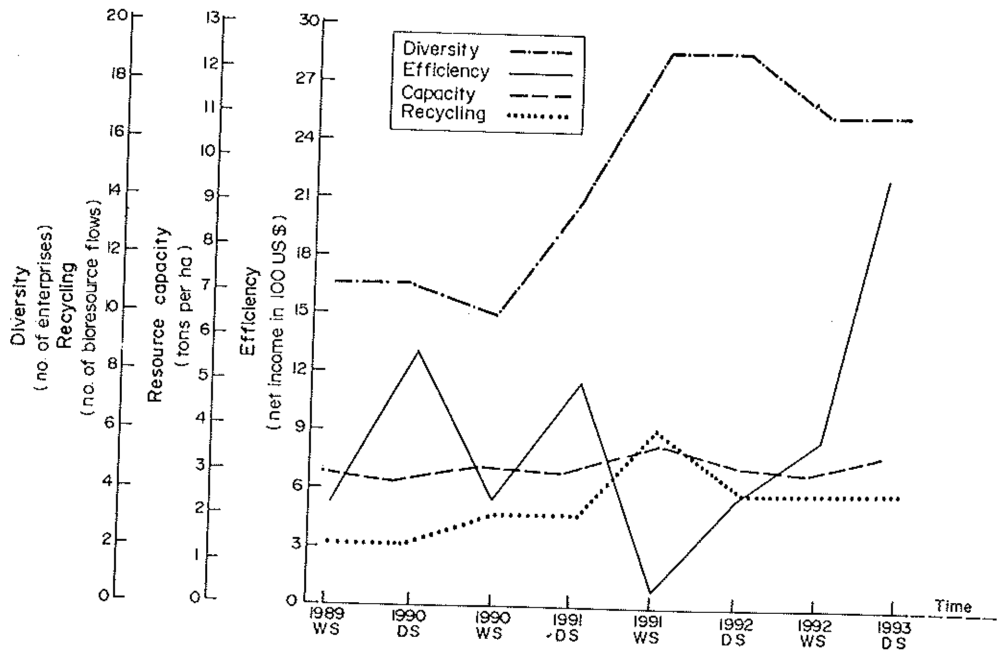


Fig. 7. Farming systems sustainability indicators for Farmer 2, Cavite, Philippines. WS = Wet season, DS = Dry season.

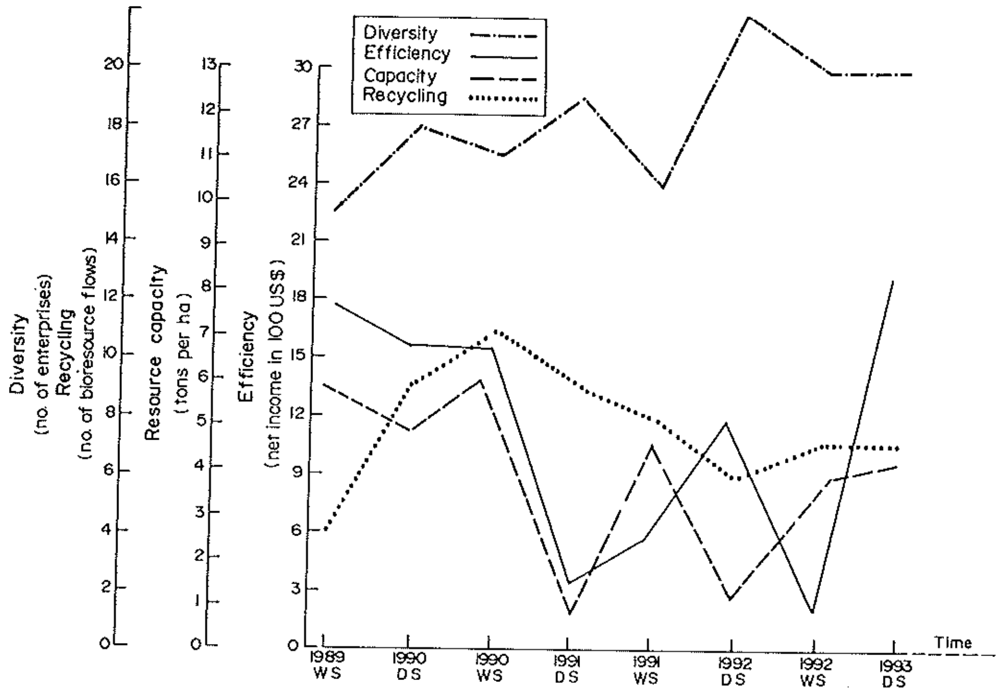


Fig 8. Farming systems sustainability indicators for Farmer 3, Cavite, Philippines. WS = Wet season, DS = Dry season.

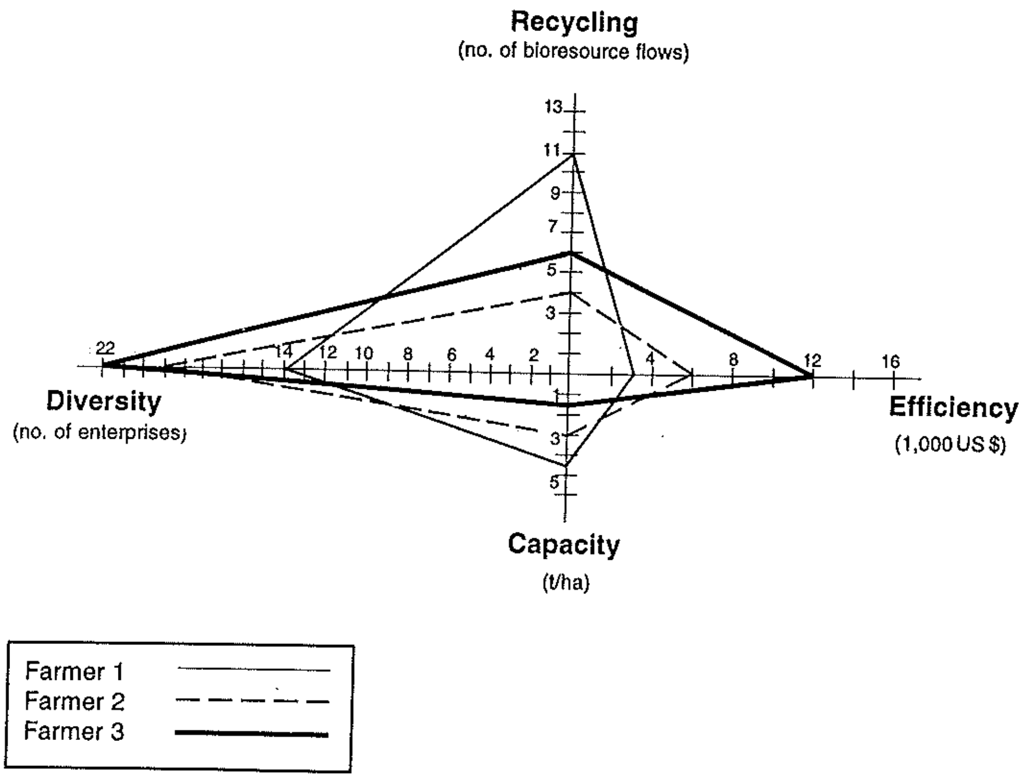
anticipated urban demands. Farmer 2 reduced recycling and diversity because he handed most of his land over to his son. As a result, his water supply is now too uncertain to maintain vegetable and fish culture at previous levels.

Reversals in terms of seasonal profits occurred everywhere. Farmer 1's economic efficiency was high in the wet season and low in the dry season, but farmer 2's was the reverse. The explanation is simple: Farmer 1 sells wet season rice and has off-farm employment in the dry season, while farmer 2 sells dry season irrigated vegetables and consumes wet season rice. Perhaps more interesting is the reversal of farmer 3. Here economic efficiency started out higher in the wet season and then shifted to the dry season half-way through. The reason is that his fruit trees started bearing fruit and he started rice-fish culture in the dry season. A further dimension to our confusion is the variation in farmers' valuation of their own time and what are thought of as "free" inputs like grazing land, tree and grass fodder, wood and manure. Giving a value for these bioresources is beginning to be perceived as important by farmers and researchers alike.

While assessment of sustainability indicators over time is vital for anyone trying to understand sustainability, it is not an easy instrument for comparing systems. For comparison of farming systems at any moment in time, we use a four-way plot of the sustainability indicators. Plots of farming system sustainability indicator kites for each farm are shown in Fig. 9. These kites provide, in their area and shape, an at-a-glance assessment of farming system performance. We quickly see how a system is performing in different dimensions. However, this argument is specious and will remain so until causal links between sustainability indicators and sustainability can be demonstrated. Given these assumptions, it is tempting to suggest that when economic efficiency is low, as when the vegetable crops of farmers 1 and 2 failed, performance in diversity and recycling remains strong. Perhaps investments in these indicators are a little more secure than profits. Happily the performance of farmer 3 suggests that you can also have it all: diversity, recycling, capacity and economic efficiency.

It is too early to say that these analyses and data presentations reveal new information and provide new insights into farming system sustainability or affect changes in household natural resource management decisions. We are, however, sufficiently confident in these methods to continue with more time series data, covering a larger number of farm households. We are designing a computer software called RESTORE to capture the farmer monitoring data, print out all the diagrams, and conduct the impact assessments right in front of the farmers.

Fig. 9. Farming systems performance indicator kites, Cavite, Philippines.



CONCLUSION

The preliminary nature of this work permits few definite conclusions. There is, however, little doubt in our minds that indigenous knowledge must be the foundation of experimentation in natural resources management. Farmers do have indigenous categories for natural resources and this knowledge allows research to start with the farmers. Once researchers have learned it, indigenous knowledge provides a common language for researchers and farmers to begin and keep talking. The dialogue between farmers themselves and with researchers about natural resources and how they might be rehabilitated is made possible through pictorial models of bioresource flows. We are sure that farmer groups and NGOs provide the right mix for farmer-to-farmer skill building to occur. There is no doubt that farmer participation must make the jump from information gathering to farmer skill building in experimentation and decisionmaking. Lastly, our experience supports the notion that impact assessment must be built into the experimental process. This is particularly true when "rolling" experimental designs are used to determine the direction of change toward sustainable farming systems.

More work is needed to further explore and develop reliable sustainability indicators. The simplistic counts of flows and species for estimating recycling and diversity need to be tempered by estimates of the volume of flows and size of cultivated areas or abundance of species. A more direct measure of natural resource quality needs to supersede our biomass estimate of their capacity.

Just as important as improving our indicators is improving the valuation of bioresource flows. Farmers consider tree and grass fodder gathered from communal land as free, just as are wood and fish gathered from hillsides and streams. Given the emerging importance of these resources for sustainable agriculture, a much more rigorous accounting of their value will be attempted in the future. A last area for further improvement will be a more systematic way to examine levels above the system boundary that we have drawn. The observation that farmer behavior was strongly influenced by land tenure and urban markets drives home the need for this.

Even though we stress the preliminary nature of this work, insights about sustainability and natural resources management are becoming apparent. The observation that productivity need not be compromised in the pursuit of sustainability suggests that when examined at the farm level, there may be no need for trade-offs between the two. The dynamism and reversals that have occurred since 1989 suggest that sustainability may not be characterized by stable inputs and outputs and stable income as was originally thought. The ability of a farming system to change and adapt to opportunities may be more important. We might think of this character as evolvability. A further insight of interest to farming systems researchers is that farmers are not as expert at natural resources management as they are at profit maximization. Farmers told us that this was the first time they had seen their farms in this way. Thus, linking farmer participation and quantitative analysis with a natural resource focus may change not only the way researchers generate new technologies for sustainable farming systems, but also the way farmers manage their natural resources.

ACKNOWLEDGMENTS

We wish to thank the International Institute of Rural Reconstruction (IIRR), Cavite, Philippines, for their active role in this ongoing collaborative research effort. We are especially grateful for the inputs and support of Julian Gonsalves, Scott Killough, Nestor Roderno and Eusebio Imperial, all of IIRR, as well as of our ICLARM colleagues Teresita Lopez and Farlyz Villanueva, for their participation and contribution in field work and data processing. Lastly, we would like to acknowledge David Norman for helping us think through progression in farming systems research focus, which resulted in our Fig. 1.

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