

Economics and Agroforestry¹

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Abstract: The concept of sustainability is an underlying theme in much of the literature dealing with the economics of agroforestry. Four major areas of concern for economic investigation into sustainable agroforestry systems—profitability, dynamics, externalities, and markets—are addressed using examples from the available literature. Finally, the social constraints that farmers face when adopting agroforestry technologies are discussed.

Upon examining the literature on the economics of agroforestry, one is struck by two reoccurring themes—sustainability and farming systems research and extension (FSR/E). Sustainability is often the justification for much of the work being done in agroforestry. Reid (1989) states that, worldwide, as much as one-half of all forest clearing is done to replace degraded agricultural land. However, the removal of forests is often counterproductive because trees, either used in rotation with other crops or grown concurrently with them, are seen to allow the maintenance of a higher level of soil fertility than continuous monocrop production (Weirsum 1981, Vergara 1987, Kang and others 1989). Farming systems research and extension is frequently recommended as the preferred method in dealing with the complexities of agroforestry systems and with their introduction into complex social systems (Michie 1986, Wallace and Jones 1986).

Sustainability is often a vaguely defined concept (Batie 1989). An example is the definition given by Harwood (1988) as quoted by Francis and Hilderbrand (1989): ... an agriculture that can evolve indefinitely toward greater human utility, greater efficiency of resource use and a balance with the environment that is favorable both to humans and to most other species.

A somewhat better definition is that of the World Commission on Environment and Development (Reid 1989):... meets the needs and aspirations of the present without compromising the ability of future generations to meet their own needs.

Both of these definitions express the basic precept that we should not rob future generations to fulfill our current greed. However, they do not provide much guidance as to how to proceed towards a sustainable agriculture; rather, they are statements of an ethical position. Reganold and others (1990) provide a description of what sustainable agriculture should be: For a farm to be sustainable, it must produce adequate amounts of high quality food, protect its resources and be both environmentally safe and profitable.

This is both a definition of a sustainable farm and a list of conditions which must be met in order for the farm to succeed. The first condition is that the farm must provide adequate amounts of high quality food. This also implies that the farm must satisfy

the demands of its markets. This is true whether the produce is consumed on the farm or if it is sold.

The second condition is that the farm must protect its resources, a reference to the dynamic aspect of sustainability. The farm exists not only in the present, but also in the future. The farmer must take into account the usage and stock of his resources over time.

The third condition is that the farm must be environmentally safe, a reference to what economists call externalities. Farming systems have effects both on and off the farm. Off-farm externalities, such as sedimentation and chemical pollution of water supplies, must be considered in the social valuation of farming systems. Finally, the farm must be profitable. The farming system must meet the needs of its operators. A farmer does not farm without constraints—societal constraints, the limits of his time, and financial and physical constraints. To be adopted, a farming system (e.g., agroforestry) must meet a farmer's needs better than alternative systems.

Reganold and others have provided four areas of concern for economic investigation into sustainable agroforestry systems: 1) profitability, the farmer's behavior of optimizing subject to constraints, 2) dynamics (time), 3) externalities and 4) markets. The remainder of this paper will discuss each of these areas.

Profitability

Much of the economic research in agroforestry has focused on how to maximize the output of the farm given the physical, financial, and time constraints of the farmer. In contrast, little work has been done to examine how this maximization is affected by the social constraints faced by and values of the farmer.

The most common theoretical approach taken is to start with the development of a production possibilities frontier (PPF) (Filius 1981). Sometimes the PPF is simply labeled as a theoretical demonstration of biological competition (Hoekstra 1990). The PPF is drawn with the maximum potential quantity of a crop on one axis and the maximum of a forestry product from the same area on the other axis (fig. 1). A straight line between the two points represents the output combinations of the plot if different fractions of it are used in the production of the two crops. Point A in Figure 1 is the output of a 50-50 mix of the two monocultures. All points on the straight line have a land efficiency ratio (LER) of one (Vandermeer 1989).

Field trials are then performed using an intercropping system in various combinations, and these points are plotted on the same graph. Points that lie above the straight line are said to have a LER greater than 1.0, and points that lie below the straight line have a LER of less than 1.0. Points with a LER of less than 1.0 indicate that better yields can be obtained by monocropping the area. Finally, the points that form the outer boundary are con-

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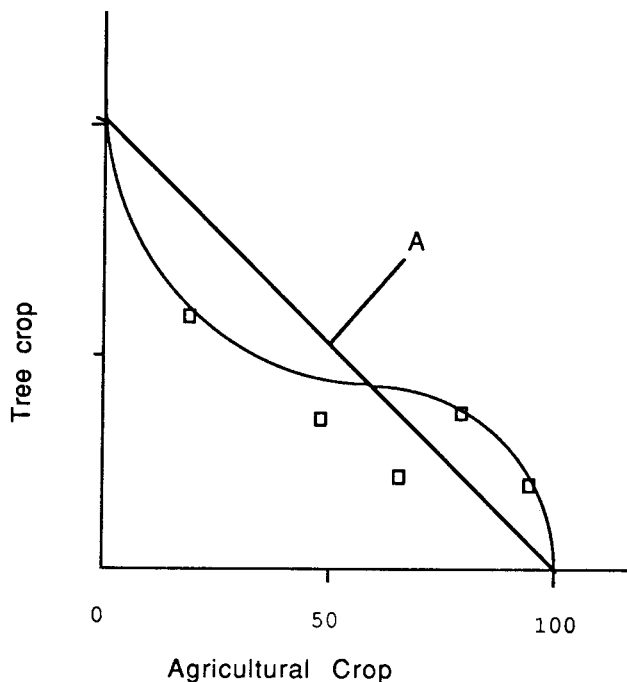


Figure 1-The diagramming of hypothetical yield set (after Vandermeer, 1987). The curved line shows the maximum yields under an agroforestry system, and the straight line indicates the maximum yields under various proportions of monocropping

nected, and this is the production possibilities frontier (PPF), or the yield set (Vandermeer 1989).

Several problems exist with this approach. First, a PPF presents only a single set of inputs. If the quantity of labor or of any other input varies between the trials, the resulting curve is not a PPF. Second, the PPF shown in figure 1 does not show the maximum possible production for each combination of land use. Figure 2 shows that the intercrop can be combined with the monocrop system to give a larger production over part of the range of combinations. Third, if the trials use different combinations of inputs and produce different combinations of outputs, then it cannot be told from a graph such as figure 1 which trial is economically superior for the farmer. Finally, the information requirements for such an approach can overwhelm a research program.

A better way to work with the static (timeless) analysis of production trials is to use the partial budget approach (Etherington and Matthews 1983). A partial budget starts with the current farm condition, and then looks at how changes affect the farm's budget. It investigates the cost of the change and the benefit to the farmer. It is referred to as a "partial budget" because it does not look at the whole farm budget, but rather examines only the changes in income produced by a change in activities. Hoekstra (1990) discusses some of the valuation questions in assembling partial budgets. In a ICRAF working paper, Hoekstra (1987) lists published sources of information and provides a more thorough discussion of the methodological issues involved in data collection for economic analysis.

A most important concept in the partial budget is the opportunity cost of a change. For example, in introducing alley cropping to a farmer's corn field, one of the things being given-up is

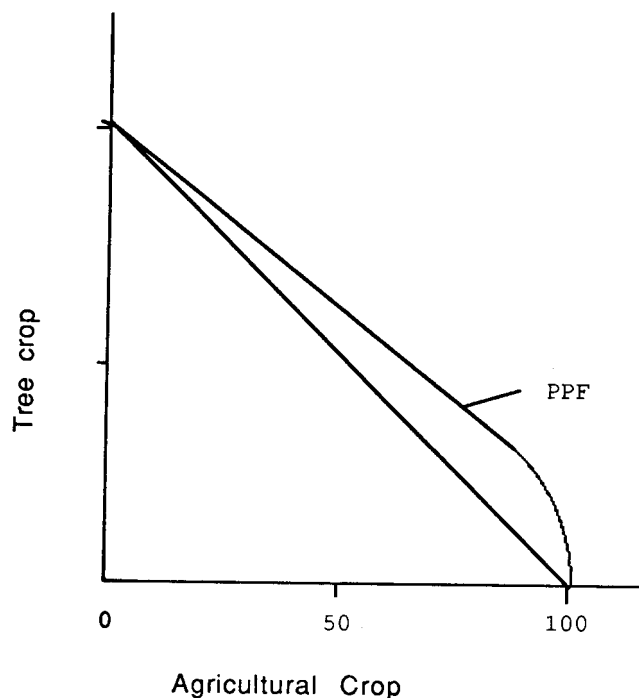


Figure 2-The production possibilities frontier is the outer convex set of points under all combinations of alternatives including a combination of monocropping and agroforestry.

the corn that could have been grown in the space the trees are now using. This is an opportunity cost. To demonstrate partial budgeting, an example analysis (table 1) on adopting a sorghum-*Leucaena* alley cropping system in a semi-arid of India (Singh and others 1989) is reproduced here. It is typical of the type of analysis one finds in the literature.

The introduction of *Leucaena* alleys is considered to be an addition to the current practice of monocropping sorghum. Therefore, the opportunity cost is the sorghum forgone by adopting the sorghum-*Leucaena* system. Table 1 provides a summary of the partial budget analysis and gives the opportunity cost on top and the gains from alley cropping on the bottom. It appears from this analysis that the net-gain from converting from a sorghum monocropping system to the sorghum-*Leucaena* alley cropping system is 5,015 Indonesian rupiahs (INR) per hectare.

The one weakness in this analysis is that the differences in inputs between the two systems is not taken under consideration. In particular, there is no mention of the differences in labor requirements. Labor is seldom a "free good." Unless the farmers do not have any alternative use for their labor and they do not value their leisure, then the differences in the labor requirement must be included in the analysis. The analysis would then look as shown in the column of Table 2 headed "year 1." Here it is assumed that 1) labor is the only input, 2) the farmers value their labor at INR 4 per hour, and 3) sorghum requires 500 hours of labor while alley cropping requires 1000 hours.

With the inclusion of the labor costs, the net-gain from alley cropping is decreased to INR 3015 per year. This is still a considerable increase in income from the introduction of alley farming.

Table 1-An example partial budget analysis¹

	Yield (t/ha)	Price INR/t	Revenue INR/ha
Sole crop sorghum			
Grain	1.55	2250	3488
Stover	5.1	500	<u>2550</u>
Total			6038
Alley cropped sorghum-Leucaena			
Grain	1.09	2250	2453
Stover	3.9	500	1950
Fodder, in-season	7.2	250	1800
off-season	3.1	500	1500
Fuel, stems	6.5	300	1950
stumps	3.3	400	1320
Seeds	0.4	200	<u>80</u>
Total			11053
Net gain			5015

¹Adopted from Singh and others (1989), using the high, in-season prices for sorghum grain and stover.

Table 2-A hypothetical 5 year project analysis

	Year 1	Year 2	Year 3	Year 4	Year 5
Sorghum					
Total revenues	6038	6038	6038	6038	6038
less input costs	<u>2000</u>	<u>2000</u>	<u>2000</u>	<u>2000</u>	<u>2000</u>
net-income	4038	4038	4038	4038	4038
Sorghum-Leucaena					
Total revenues	11053	11053	11053	11053	11053
Less input costs	<u>4000</u>	<u>4000</u>	<u>4000</u>	<u>4000</u>	<u>4000</u>
net-income	7053	7053	7053	7053	7053
Net-gain from adopting alley cropping	3015	3015	3015	3015	3015
Discount formula	1/1.20	1/1.20 ²	1/1.20 ³	1/1.20 ⁴	1/1.20 ⁵
Discount factor	0.833	0.694	0.579	0.482	0.402
Present Value	2511	2092	1746	1453	1212
Total present value	9014				
Total present cost	10000				
Net present value	-986				

Dynamics

The second aspect of a sustainable farm are the dynamics or time dimensions. Often the concept of dynamics is dealt with by adding a third dimension of time to the PPF and showing how the shape of the PPF changes with time (Etherington and Matthews 1983), or it is shown in a plot of how soil status changes over time as the proportion of land used in trees and agricultural crops varies (Huxley 1989). However, again the partial budget approach is much easier to apply.

Table 2 demonstrates how changes in output over time due to different cropping methods are normally compared in a partial budget analysis, by calculating a net present value (NPV). People normally require a reward for postponing gratification. This is why banks pay interest on deposits. An investment in soil fertility is very similar to putting money in a bank. It requires a dividend in the future for one to make the deposit and forgo current consumption. The amount of dividend is measured by the use of a discount rate. This is the “interest rate” which farmers use to compare present and future consumption.

If the farmers discount rate is r , then the promise of one dollar n -years in the future is worth $1/(1+r)^n$ to the farmer now. For example, at 20 percent, 100 dollars five years from now is worth $100/(1.20)^5$ or \$40.19 now. In other words, if \$40.19 were put in the bank now at twenty percent interest, it would be worth \$100.00 five years from now.

To complete table 2, it is assumed that the investment in ally cropping in the example requires 1) an investment of INR 10,000

per hectare in the year before cropping begins, 2) the discount rate the farmers use is 20 percent, and 3) the project’s benefits last for 5 years. Economists at the CIMMYT have found that a 40 percent return is the minimum general rate that small farmers will accept (Harrington 1982). However, this figure is not uniformly accepted. The discount rate used by farmers is a suitable subject for research.

In table 2, each of the net-gains have been discounted back to year zero, the year of the first investment. The total present value of the net-gains is then calculated as the sum of the discounted values from each year. This totals to a present value of INR 9,014. The costs of the project in year zero are not discounted as they occur at the beginning of the project. Thus, the net present value (NPV) is the difference between the present values of the costs and of the benefits or a negative INR 986. In this example, the farmer would not undertake the project. If the project produced a sixth year of benefits, then it would have a positive NPV, and the farmer might consider it more favorably.

This example demonstrates one of the problems of sustainable agriculture. Unless the NPV of all future gains due to the increases in soil fertility exceeds the gains from mining the soil in the present year, the farmers most likely will not adopt sustainable agriculture practices.

Externalities

The third component of sustainable agriculture is the social or external aspects. Generally, these are the most difficult class

of effects to value economically. They include such things as protection of the reef and fisheries, avoiding pollution of the water supply, and building food reserves for the community in case of a crop failure or a natural disaster (e.g., a typhoon). The general concept is that society should be willing to make an investment in preventing the effects of non-sustainable agriculture systems that occur off the farm. The criteria and calculations are the same as for the farmer in that the present value of the gains must exceed the present value of the costs over the life span of the project. The difficulty usually lies in valuing the changes produced by the proposed projects (e.g., a decrease in the pesticide level in drinking water).

Vogel (1989) discusses the implications of increasing the scale of the economic analysis from the farm level to a broader social perspective, however his discussion does not cover the inclusion of externalities. Daru and Tips (1985) discuss the social and economic factors affecting farmer participation in a watershed management and agroforestry intensification project in Java which was designed to deal with these externalities, but they do not analyze the costs or benefits. In fact, in the literature it appears that few examples of this type of analysis have been applied to agroforestry projects. Further, a more complete analysis of the methodology is beyond the scope of this paper.

Markets

The fourth area of sustainability is markets. Reeves (1986) claims that "marketing is arguably the most neglected issue in farming systems research." Marketing often receives a token amount of attention during the initial survey phase of project, but then little attention is paid to it afterwards (Reeves 1986).

Marketing includes everything that is done to the product from the time that it is harvested to the time that it is consumed. Reeves' study deals with the choice of marketing channels made by small grain farmers in the Western Sudan. It is useful in its demonstration of the partial budget approach, and how the budget is affected by the prices received through differing marketing channels. It also deals with the reasons why the farmers use the different channels even though the price that they receive varies considerably with the choice of marketing channel used. Reeves is an economic anthropologist, and his approach is a good example of the mixing of scientific disciplines.

Other marketing considerations would include: 1) the availability of shipping and storage facilities, 2) the seasonal and year to year price changes that affect farmers and their risks, and 3) the desirability of the product in the market. The problem of consumer acceptance has led to the downfall of many well-intentioned projects.

Social Constraints

Finally, consideration must be given to the individual and social constraints that farmers adopting agroforestry may have to face, and the possibility that producers may have goals other

than profit maximization. Olofson (1985) surveyed farmers using traditional agroforestry techniques in the Philippines. Among the constraints that he found modifying the farmers' behavior were: 1) age of the farmer, 2) lack of available family labor to the farmer, 3) prior erosion, hardpanning, and steepness of individual plots, 4) distance to individual plots and the relative weight of the different potential crops, 5) prior cropping patterns on borrowed land that needed to be continued, and 6) the lack of a draft animal which required borrowing an animal and its owner, and returning a favor later.

Francis (1989) investigated land tenure systems and how they affected the adoption of alley farming in Nigeria. He found that the ownership of land and the right to plant trees did not necessarily coincide and that these tenure systems "are crucial in determining the acceptability and viability of alley farming."

Rocheleau (1987) divides the management of farming tasks into three areas: control of the resource, responsibility to provide a product, and labor for the tasks. She points out that the division of these between family members will vary among the multiple areas of a farmstead. In fact this distinct division among multiple users within a "family unit" can extend to a single tree species which may provide differing resources to each family member.

Economists recognize that farmers may not be maximizing profits. The most common alternative thesis is that the farmers are maximizing their expected utility under conditions of uncertainty. This is simply a way of dealing with the risks facing farmers and with the fact that they are frequently observed *not* maximizing expected profits.

There has been little study of multiple goals such as subsistence, status, leisure, and cash flow management. Barnett and others (1982) tested a multi-objective, goal-programming model in attempting to explain the behavior of Senegalese subsistence farmers. They concluded that it did not offer any better predictive power than did the profit-maximizing hypothesis.

Conclusions

In conclusion, most economic analysis of agroforestry systems has been descriptive. Where quantitative analysis has been done, most have taken the form of partial budget analysis. In the area of general economic analysis of agricultural development, the inclusion of risk-avoiding behaviors by farmers has been a response by economists based on the observation that farmers do not always adopt high yielding cultivars. The dynamic aspects of agroforestry and sustainable agriculture have not been given as much quantitative analysis as they deserve. Little quantitative work has been done in the area of externalities and agroforestry, although there has been some work by environment economists dealing with agricultural externalities. Social system constraints have mostly been dealt with by anthropologists. Finally, economists need to develop better methods to deal with multiple goals of farmers who operate partially or largely outside of the market system.

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