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Not Out of the Woods Yet: Challenges for Economics Research on Agroforestry

Sara J. Scherr

Tropical farming systems include a rich variety of agroforestry practices, namely those in which woody perennials (trees, shrubs, palms, and bamboos) are deliberately grown in association with crops or livestock (Nair). These range from extensive systems such as enriched woody fallows, protected trees in crop fields, or riparian grazing reserves; to interstitial plantings such as field borders of timber trees or woodlots on marginal farm sites; to intensive systems like home gardens or alley-cropping (Raintree).

In recent years, the international community has begun to recognize the potential value of agroforestry in tropical land use. There has been a sharp increase in development spending (FAO) and a new focus on agroforestry in international agricultural research centers (CGIAR). Interest has been spurred by recent research findings. Trees and shrubs provide food, shelter, farm inputs such as fodder, medicines, and raw materials (wood, fibre, dyes) critical to subsistence and income of many rural households (Falconer). Trees can protect or improve the environmental resource base for crop and livestock production, through windbreaks, erosion barriers, improved soil fertility and physical properties, field drainage, microclimate improvement, and wildlife habitat (Young). In some regions, woody perennials are more environmentally sustainable than permanent annual cropping (Ruthenberg). In many regions, farm trees (rather than forests or commercial plantations) are the main source of current and future supplies of fuelwood, timber, and other important tree products (FAO).

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However, existing and potential economic contributions of agroforestry have not been rigorously examined, making it difficult to set development and research agendas. Recent reviews (Swinkels and Scherr; Scherr 1991; and Sullivan, Huke, and Fox) show that most economic studies have focused on location-specific assessment of financial returns from particular practices. Only a few have examined agroforestry in the context of regional land use change, relative returns to productive factors, or household decision making.

Key requirements for more effective use of economic analysis in agroforestry development policy and program design include the following: *(i)* development of a theoretical framework for analyzing the economic role and potentials of agroforestry in farming systems; *(ii)* development of better methods of incorporating agroforestry into models of household decision making; and *(iii)* generation of economic data on agroforestry, including development of more effective and efficient methods of data collection. This paper examines each of these challenges in turn and suggests some promising approaches. Illustrations are drawn from field research in western Kenya.

Agroforestry in Farming Systems Development

Our understanding of historical patterns of agricultural intensification and change in tropical farming systems provides a theoretical basis for development policy (Boserup, Ruthenberg). No comparable theoretical framework yet guides agroforestry policy. For example, Ruthenberg identifies some agroforestry potentials in his analysis of the "development paths" of major farming systems, but his treatment of tree production is incomplete and unsystematic.

The evidence from agroforestry project experience and indigenous agroforestry often suggests (implicitly) hypotheses about the economics of agroforestry in farming systems. Researchers are now beginning to systematically analyze the apparent relationships between population density, intensity of land and labor use in farming systems, markets, and agroforestry practices adopted by farmers (Raintree; Arnold and; Dewees; Berenschot, Filius, and Hardjosoediro; Mary and Michon). Some common patterns of agroforestry intensification can be identified.

Incentives for Agroforestry Intensification

The history of official agroforestry development efforts reveals that failure of projects and policies frequently results from a mismatch between the interventions promoted and farmer incentives to practice them. Evidence suggests four types of long-term pressures induce farmers to intensify tree husbandry. The first two are obvious to economists: declining access to wooded land, which reduces tree product supply; and increasing demand for tree products resulting from population growth, new tree uses or products, or new markets.

The third, increasing population density and declining farm size, may create a social need for trees and shrubs as fences or boundary markers. In the fourth case, land users may respond to declining land quality by protecting or planting trees and shrubs for windbreaks, soil fertility, erosion control, waterway protection, grazing land rehabilitation, or by substituting woody perennials for row crops on erodible soils.

The rate and degree to which land users respond to such incentives is influenced by availability of alternate supply sources and substitutes, and by suitable agroforestry technology (e.g., tree species that grow well with crops). Where sufficiently attractive, farmers replace extensive gathering strategies with increasingly intensive production strategies, as they did (pre-) historically for crops. Agroforestry policies that reflect and respond to the realities of farmer incentives stand the greatest chance of success.

How Intensification Occurs

The most effective agroforestry interventions have been those assisting farmers to manage agroforestry at an intensity appropriate to existing incentives, rather than to prematurely adopt very intensive systems (Raintree).

Gathering strategies are still widely used by farmers to supply food, fuel, fodder, medicines, and construction materials from naturally growing trees and shrubs in fallow, farm, communal or forest lands (Dewees, FAO). Gathering will be more economically attractive to farmers than more intensive systems as long as it provides a reliable supply of products at a lower cost.

When land (or high-value tree) resources are more restricted, land users become interested in managing naturally growing trees to improve tree establishment, to increase yields, or to ensure sustainable supply and harvest rights. Management may be communally regulated. Many such systems are economically and environmentally sustainable and can be made more productive through innovations in technical methods, organization, tenure arrangements, or marketing (May, Nair).

Where valuable naturally growing species become scarce or harvest rights are uncertain, land users may domesticate them; that is, establish them where they can be more easily protected, managed, and used (Dewees, Nair). Germ plasm distribution programs and research on propagation methods can accelerate this process.

As incentives for tree growing rise, farmers expand the scale of production. Species highly competitive with crops or grasses will be planted mainly in the farm's interstices (borders, homesteads, or steep sites), or in separate blocks. Conventional "farm forestry" practices and early adoption of commercial tree crops fall in this category. Good intercropping species will be grown in mixtures or lines in crop or grazing land. Useful interventions might include better establishment methods or superior germ plasm, but farmers still find it economic to achieve higher production by investing in greater numbers of trees rather than in more intensive management (Mary and Michon; Berenschot, Filius, and Hardjosoediro).

With limits on available land, yet higher tree production must come either by substituting trees for crops or by increasing system productivity. The latter may come from more intensive management, higher-yielding components, or more complementary combinations or spacing of tree and crop components (Nair, Raintree), suggesting a useful role for research. Intensification proceeds most rapidly for more highly valued tree products and services. This partly explains the high management level historically achieved for tree products such as coffee, oils, nuts, fruits, and spices, with high value weight ratios and high income elasticities of demand.

Analysis identifying economic levels of agroforestry intensity for various purposes is needed for local and regional program planning. In my view, current agroforestry development efforts tend to overemphasize tree planting, overlooking opportunities to support farmers in tree resource management and tree domestication, while research efforts overemphasize high-intensity systems even where these are not congruent with farmer agroforestry incentives.

An Example: Agroforestry in Western Kenya

The food crop-livestock system of the Luo tribe in western Kenya[1] illustrates patterns of agroforestry intensification in upland cultivation systems, and the role of outside intervention. The study area in Siaya and South Nyanza districts lies at 1,000–1,500 meters altitude, with 800–2,000 mm average rainfall and low fertility soils.

Several factors led to land use change in the districts in the last century. Average population density rose from very low levels to 100/km2 by 1948 and around 250/km2 by 1990 (with much higher densities in high rainfall areas). Area in common lands declined, as did fallow land for soil rehabilitation or gathering of tree products. A third factor was the rise of commodity food production in the 1950s, and growing local cash incomes from trade and wage labor.

Three agroforestry periods can be identified. In the late 1800s and early 1900s the farming system was oriented to subsistence, with fallow-based cropping and an important pastoral component. Farmers relied for fuelwood, building wood, medicines, food, and fodder on tree products gathered or managed from naturally growing trees. With permanent settlement, farmers established farm and homestead boundary hedges of sisal and euphorbia. Fruit and timber species were protected in farm fields, and some especially valuable species were domesticated. Several exotic fruit and hedging species introduced by traders and travelers diffused widely and quickly. Colonial efforts to promote farm woodlots, however, were rejected.

By the mid 1900s, deforestation and permanent settlement had sharply reduced off-farm land and tree resources. Increased population meant higher demand for wood products. Building-quality wood became scarce. In response, farmers began to domesticate local tree species and to adopt exotic timber species. Interstitial tree planting became common, with little external input other than seedlings grown in central government nurseries. Naturally growing trees were more intensively managed and timber trees were scattered or planted in noncropped areas of the farm, field borders, or occasionally wood lots. The region produced maize for export to the rest of Kenya in the 1950s and 1960s, but with inadequate soil management. To counter declining yields, some farmers began to enrich fallows by scattering seed of indigenous nitrogen-fixing shrubs, and to use leaves from trees in crop fields to mulch crops.

In recent decades, average farm size has declined sharply and the transition to permanent cropping has begun. Soil degradation and yield decline have been accompanied by chronic cash shortage and labor migration. Local cash markets for fuel, poles, seedlings, and fruit have grown up. Farm trees have become the main wood source for most rural families, and a modest source of income. Farmers have thus begun to try more intensive agroforestry practices.

Drawing from local innovations and extension programs offering a "basket" of options, tree domestication, scale of planting and management intensity have all increased for different species. Farmers receiving an average of three years' extension assistance from CARE have more than doubled the average density of farm trees. In 1989, the average 2–3 hectare farm had 539 trees and 386 meters of hedge. Species diversity has remained high (with 176 species of which 30 are commonly planted). But nine species have become dominant (73% of the total), each suited to a particular use or farm niche; three are excellent intercropping species.

On-farm tree nurseries for seedling production have become widespread. There has been intensive tree planting in homesteads and homegardens, and economic species have been incorporated into live hedges. Half of all new farm trees (and 40% of older trees) on CARE-assisted farms were sited in or around crop fields. Thousands of farmers have begun experimenting with protective practices such as windbreaks in dry

[1] This section draws on the author's research on the impact of the CARE Agroforestry Extension Project on Luo farmers' agroforestry practices. Methods included a review of colonial archives and forest department records, farmer and group interviews, and a formal survey of participants. The survey drew data from 336 farmers about the farm household, extension contacts, trees grown on farm (including niches, species, period of establishment, use, and management), sources of household tree products, and cash sales. The sample was stratified by agroecological zone (Scherr 1992, forthcoming).

areas and alley-cropping and contour hedges in wetter areas (Scherr 1992, forthcoming). Interventions to improve market efficiency and research to develop more intensive systems are now economically justifiable.

Research Directions

Agroforestry potentials for other upland cultivation systems under population pressure may resemble those of the Luo; they are likely to be quite different for other types of farming systems. Conceptual models of agroforestry potentials under different land use conditions would assist policy and research formulation. To develop such models will require historical and comparative analyses of farmer management of tree resources under different agroecological, socioeconomic, and policy conditions. Pingali, Bigot, and Binswanger's study of agricultural mechanization in African farming systems provides an example of such research.

Modeling Agroforestry in Household Decision Making

Farmers' decision making about the choice and management of agroforestry practices has been shown to be an integral part of the overall strategy for ensuring subsistence, cash income, and savings in many farming systems (Arnold and Dewees, Falconer, Nair, Raintree). In the western Kenya example, agroforestry practices reflected farmers' strategies to reduce labor demand (by producing fuelwood in near fields), improve food security (by green manuring), and reduce cash expenses (by farm production of building poles). Farmers' labor, land, and cash constraints influenced choice of sites for tree-growing and management practices (Scherr 1992, forthcoming).

Household models can address several key questions, including the following: *(i)* how households choose management practices for a given agroforestry system (such as the optimal frequency of pruning in alley-cropping or the optimal fallowing cycle in shifting cultivation); *(ii)* how households choose between alternative strategies to meet defined needs for tree outputs (for example, whether to obtain fuelwood by thinning timber stands, collecting deadwood in woody fallows, or planting fuelwood plots); and *(iii)* how different groups of households allocate land, labor, capital, and management resources among agroforestry and other production, investment, gathering, or employment activities.

Household decision-making studies should be a valuable input in the development of effective agroforestry policy. For example, low productivity of many agroforestry systems reflects a historical dearth of technical research. Household studies may identify priority research areas in which productivity improvements would have a significant effect on farm practices. Pricing policies often are biased against tree production. For example, they subsidize output or input prices of crops, but not of trees; they maintain artificially low prices of competing wood supplies from national forests; or they provide subsidies on inorganic fertilizers and animal feeds that reduce farmers' incentives to produce leafy biomass on-farm. Household studies may also be used to evaluate the effects of price policy changes on the extent, mix, and benefits from agroforestry practices. Yet only a few tropical studies to date (Dewees, May) have linked rural households' decisions about tree production to their consumption of tree products or to market factors such as the relative prices of outputs, inputs, substitutes, and alternatives.

Modeling Weaknesses

Theoretically, agroforestry systems can be treated in household models simply as additional production sectors. However, much of the modeling work done so far (see references in Scherr 1991, Sullivan, Huke, and Fox, Swinkels and Scherr) has been disappointing in its treatment of basic features of agroforestry systems.

Multiple outputs. A major feature of agroforestry systems is the presence of multiple outputs. Methods have been drawn from modeling multiple cropping and multioutput forest and livestock management, but agroforestry analysis also demands treatment of the interactive effects of tree and crop management, and of multiple tree components.

Intertemporal variability. Agroforestry systems are perennial and changes over time have important economic effects. Some intertemporal factors have been treated in agroforestry models, such as the life cycle of perennial components and effects of trees on soils or water quality over time. Others have not, such as lagged effects of earlier management decisions; seasonal variability of the associated annual crop species; and irregular production patterns caused by harvesting trees only when other foods are scarce or to meet special expenses. Few models account for the often greater flexibility in timing of tree establishment, management, and harvest (relative to annual crops), which permits adaptation to labor and capital availability. In marginal agroforestry systems, inputs may largely be residuals from other activities (Falconer, Arnold and Dewees).

Multiple economic roles. In many studies, the economic roles of agroforestry systems are improperly defined. A windbreak for crop fields can be handled as an input (for crop production), a product (for fuelwood harvests), an investment (for long-term timber harvest), or a fixed asset (a naturally growing stand). The choice depends upon its actual establishment and management. Noneconomic benefits critical to decision making are often left out of the models.

Spatial factors. A key challenge in modeling agroforestry systems is to account for spatial factors. Management practices determine whether interstitial systems (such as a field border) should be modeled to displace or to supplement cropland. Spatial arrangements of trees and crops in intercropping affect both management and output. Distance from the household to woody resources is a key determinant of agroforestry adoption and management. Yet realistic treatment of spatial variables is absent from many models.

Extra-household factors. Interactions between on- and off-farm management of woody vegetation often are important in analyzing household agroforestry options. Household inputs into group management of tree resources will be affected by access to on-farm resources. Land and tree tenure rules regarding on-farm and communal tree resources influence decisions about agroforestry practices. Very few studies have attempted to model these interactions.

Explanations. The paucity and weaknesses of agroforestry modeling studies have several apparent sources. Mathematics for modeling systems with multiple and interactive agroforestry components over time have not yet been fully worked out. Agroforestry modelers may also be unfamiliar with recent work from other fields on dynamic interspatial and intertemporal modeling. Some researchers feel that their field data is too limited to make complex mathematical treatments useful, particularly to inform policy.

More pernicious, however, is the temptation to which some economists have succumbed, to proceed with technical modeling exercises before reliably selecting and defining the key variables and the nature of their interactions. A good modeler understands the basic technical and management characteristics and options of the system as actually managed by farmers (at least as a starting point), and the socioeconomic context for household decisions. As such information is rarely available in libraries, a requirement of policy-relevant household agroforestry modeling is high-quality field research. Assistance from knowledgeable social scientists and technical agroforesters in this task would usually be needed.

Because of agroforestry variability and high research costs, modeling has the potential to become a central tool in analysis. Thus resolving modeling issues of special concern to agroforestry is of particular importance; solutions may also contribute to modeling of other complex crop, livestock, and forestry management systems.

Generating Economic Data on Agroforestry

Even when economists have a clear understanding of agroforestry phenomena, they often are daunted by the serious problems and/or expense of obtaining data for economic analysis. Few countries collect time series data on agroforestry land use, production, consumption, distribution, prices, or input use. It is thus difficult to confirm trends or rigorously analyze associations between agroforestry practices and other economic variables.

Nor is there documentation of the inputs, outputs, or productivity of agroforestry systems under different site conditions, with different intercrops, at different phases of the production cycle, under different management regimes. Few production functions have been developed. Even fewer data are available on associated site changes or other environmental effects (Swinkels and Scherr). Researchers may opt either to use one of the few existing data sets (though their location-specific information cannot be legitimately extrapolated to the new problem or site) or to collect new data.

Short-term surveys to fill these gaps are fraught with potential for misinterpretation. Patterns of consumption may vary with climatic conditions; for example, more fuelwood and less "famine food" is consumed in wet years. Farmers' projected production objectives and management of long-cycle systems may be unreliable.

Field data collection is further complicated by irregular field layouts, mixed-age stands, variable management, seasonally changing tree outputs, or intermittent harvests. Where agroforestry systems involve multiple users, recall and measurement data are difficult to use. Information on spatial relationships must be retained. Valuing inputs and outputs, for example, from joint production, may also be difficult (Scherr, Roger, and Oduol 1990).

Strategies for Data Collection

Agroforestry's data problems may be addressed cost effectively in four complementary ways. One is to incorporate a few key indicators of agroforestry into national land use studies (including censuses and rural surveys) with geographic information systems (GIS) to document changes in spatial dimensions of agroforestry. Several approaches are already being tested.

The second is to begin long-term economic monitoring of representative agroforestry practices to develop data sets permitting analysis of economic viability, adoption, management, and policy effects. CATIE has begun monitoring studies for several agroforestry technologies in Central America (Sullivan, Huke, and Fox).

A third element is to establish joint projects between technical scientists and economists in order to develop production functions for common agroforestry systems. Such models can be used to simulate the likely economic effects of variations in site, management, output mix, resource costs, and output prices. By modifying key parameters to reflect local conditions, economists can use such models to generate realistic values for economic studies of similar systems. The best examples of this approach are for temperate agroforestry systems (Scherr 1991).

A fourth strategy is to improve our skill in collecting and analyzing existing information. Economic analyses may be based on quantitative data from short-term field surveys and case studies, complemented by estimates drawn cautiously from historical reconstruction (based on both archival and oral sources) of land use change and household use of woody resources. This approach, used in the western Kenya case study, draws upon information from ethnographic studies, historical records, land use histories from key informant and group interviews, and aerial photo series, as well as informal and formal farm and field surveys and case studies. Ideally, agricultural economists would develop such models with assistance from agricultural historians or geographers, anthropologists, and agroforesters technically knowledgeable about the study regions. This approach may allow significant theoretical advances in agroforestry economics while the necessary data bases are being developed for more rigorous hypothesis testing.

Conclusion

Agroforestry programs and policies would gain both clarity and direction from a more comprehensive program of agroforestry economics research. Economists can play a critical role in explaining and predicting regional and household agroforestry production and consumption, assessing the economic performance and potential of agroforestry systems, and initiating regular data collection on agroforestry. There is an immediate need to devise long-term data collection and comparative studies of agroforestry in strategically selected farming systems. Such projects require international and multi-institutional planning and collaboration. The judgment and technical input of colleagues from other land-use disciplines will be needed for both theoretical development and field research.

The present paper confirms that agroforestry economics is a field still in its infancy, but with exciting intellectual challenges. One hopes that more economists will take up those challenges. With major land use changes expected in the next century, they may find their theoretical, methodological, and empirical work on multicomponent perennial systems of significance beyond agroforestry.

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