WP 2000-12
August 2000

Working Paper

Department of Agricultural, Resource, and Managerial Economics
Cornell University, Ithaca, New York 14853-7801 USA

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Presented as a Contributed Paper at the 24th International Conference of the International Agricultural Economics Association, Berlin, Germany, August, 2000.

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Over the past two decades, concerns over the negative environmental externalities associated with high input-high output agriculture, including Green Revolution technologies, has prompted increasing attention to low external input agricultural technologies on the part of development practitioners, non-governmental organizations (NGOs), donors and researchers. These technologies and practices go by many names (Lockeretz, 1989): sustainable agriculture, ecological agriculture, organic farming, low external input sustainable agriculture (LEISA), alternative agriculture, and agroecology. Although the differences between these terms and their various interpretations have been the subject of much debate, what these approaches have broadly in common is: 1) a reduced reliance on purchased inputs, which are often unavailable and/or unaffordable to limited-resource farmers, 2) the substitution of farm-household resources – notably, family labor, but also including farm residues and management capacity – for scarce purchased inputs, and 3) a focus on increasing agricultural yields among poor farmers often farming on marginal soils in less-favored lands.

Beyond these characteristics, it has also been asserted that LEISA technologies and practices further address a number of key agroecological principles, including: maintaining biodiversity; achieving synergistic crop-livestock interactions; capitalizing on system dynamics (as in nutrient cycling); increasing system productivity; conservation and system regeneration; and adaptation and innovation (Altieri, 1995). Some of the common technologies and practices which have been widely promoted under this approach are listed in Table 1. These include improved crop varieties, integrated pest management, cover crops and green manures, agroforestry and a wide range of soil conservation structures, practices and technologies.

While the yield-enhancing benefits of LEISA technologies have remained of central interest on the part of most practitioners and biophysical researchers, outside the experiment station (and sometimes within it), economic assessments have typically received much less attention (Ruben and Heerink, 1995), particularly compared to agronomic and biophysical evaluations, farmer participation and local organizational issues. This is unfortunate for several reasons, but two particular implications of this oversight deserve note. First, no matter how scale-appropriate, farmer-friendly or environmentally attractive LEISA technologies may be, it has been widely documented that new technologies and practices must be sufficiently *economically attractive* in order to be widely disseminated (Lockeretz, 1989; Lutz, *et al.*, 1994; Kuyvenhoven and Ruben, 1999). While this is a fundamental operating principle on the part of applied economists as well as many other researchers and practitioners, it is a far from universally applied principle. For example, in the growing literature on agroecological practices and research, references to and citations of economic evaluations of specific technologies are, at best, inconsistent – nearly absent in some cases (Chambers *et al.*, 1989; Altieri, 1995), and in others, present but unevenly treated (Pretty, 1995). Farm household economic and profitability criteria are often not highly prioritized among factors influencing the adoption potential of low-input technologies. Consequently, most agroecological research fails to identify suitable policy instruments for enhancing LEISA practices.

Second, since the substitution of (presumably available) labor for expensive off-farm inputs is a common feature of many LEISA technologies, evaluating the magnitude and timing of labor inputs and estimating the resultant economic returns to labor should play a central role in assessing the potential for wider dissemination of these technologies (Stocking and Abel, 1992; Low, 1993). This paper highlights first the role of labor inputs in sustainable agriculture technologies in developing countries, and then briefly addresses several specific issues which arise in the consideration of labor inputs and labor costs in evaluating LEISA technologies. The paper concludes that future work by both practitioners and researchers must devote much greater attention to this dimension of agricultural sustainability.

Labor Intensity and Labor Costs in Low External Input Agriculture

Modern industrialized-country agriculture and Green Revolution-based crop agriculture in developing countries are based on achieving yield improvements through the application of a greater quantities and quality of off-farm inputs including modern seed varieties, fertilizers, pesticides, irrigation systems, and mechanical technologies (NRC, 1989). While these technologies have proven to be highly successful in generating agricultural productivity increases in favored lands, particularly in the presence of adequate infrastructure and well-functioning input and output markets, they have been much less successful on degraded soils, on marginal and hilly lands, and in the absence of a supportive infrastructure. The simple availability of external inputs is often a concern where market access and/or infrastructure are constraints, and their affordability for farmers is equally problematic. Since farmers' abilities to access capital inputs is key to achieving subsequent yield increases, this creates a vicious cycle which limits agricultural productivity potential for those farmers who are unable to purchase or have no access to these inputs (Hazell and Lutz, 1998; Reardon, *et al.*, 2000). The severity of this dilemma – and the chronically low agricultural productivity and rural poverty which have resulted -- has led to widespread concern about how to increase farm productivity and agricultural incomes for those farmers who are "left behind" in less-favored lands – what Pretty (1995) calls the "forgotten agriculture" of drylands and wetlands, uplands, savannahs, near-deserts, hilly regions and other marginal agricultural lands.

While the availability and affordability of off-farm inputs is a chief obstacle for limited resource farmers, one input which they are widely perceived to have abundantly available is family labor. Indeed, the availability of adequate labor – and the willingness of farmers to employ labor-intensive methods – is a common, if often unstated, assumption in efforts to promote soil conservation and other labor-intensive agricultural practices (Wenner, 1980; Stocking and Abel, 1992; Ruben and Lee, 2000). Given widespread rural unemployment and seasonality in production which creates a recurrent slackening in labor demand, it is perhaps inevitable that agricultural development efforts have widely promoted farm households' investment in technologies and practices which effectively substitute the perceived abundant input (labor) for the scarce external inputs (fertilizers, pesticides, etc.). Physical soil conservation measures, in particular, are commonly noted for their degree of labor intensiveness (Harper and El-Swaify, 1988; Lutz, *et al.*, 1994; de Graaff, 1996).

Table 2 shows the labor requirements associated with a diverse set of low external input, "sustainable" agriculture practices. These figures are gleaned from the recent literature; this is only an illustrative, and certainly not an exclusive, list of technologies and practices. Numerous caveats must be employed in interpreting these data, including the fact that these technologies often are part of broader farming systems, such that it is difficult to distinguish the labor requirements of narrowly defined practices.

At least two conclusions are evident from these figures and from the broader literature from which they are drawn. First, although all of these practices commonly fall under the rubric of sustainable agriculture or agroecological practices, the associated labor requirements are dramatically different. Some practices, such as the use of live barriers, hedgerows, and no-tillage cultivation often involve relatively little additional -- or even less -- labor input compared to the conventional practices they replace or supplement. Other technologies, however, including soil conservation measures such as the construction of bench and stone terraces and the establishment of integrated agroforestry systems, are heavily labor-intensive. Simply the range of labor requirements shown suggests that, without further analysis, generalizations about the conditions under which sustainable agricultural practices are or are not appropriate must be made with great caution.

It is also clear that the range of maximum and minimum estimates of labor requirements for any given technology suggests that similar technologies and practices may involve vastly different labor requirements and opportunity costs in different countries or regions, or for farmers facing varying agronomic and economic conditions. Again, this reinforces the importance of estimating labor requirements and costs (and economic returns, more generally) relevant to individual regions and systems, not generalizing unduly from other regions or systems.

Simple estimates of magnitudes of labor inputs, of course, are of limited usefulness in assessing the economic viability of specific technologies (low input or otherwise). A more complete understanding requires the use of cost-benefit analysis, financial analysis, and other tools of economic evaluation, supplemented by the use of optimization models, production function studies, the analysis of technology adoption and other economic approaches (see Ruben, *et al.*, 2000 for a recent review). There is a growing record of these types of studies applied to specific LEISA technologies and systems, although these are typically "one-off" with/without studies of the effects of individual technologies evaluated at a given point in time. Comparative reviews of economic studies of LEISA technologies have focused mostly on soil conservation technologies (for example, see Bojo, 1992, and Lutz, *et al.*, 1994), although the recent literature also includes reviews of agroforestry systems (Current *et al.*, 1995) and crop residue mulching (Ehrenstein, 1999).

It is difficult to generalize from the extensive literature on low input agriculture; in fact, one common conclusion is that economic viability is an empirical matter, and often depends on the specific agroecological and economic situation in which the technology is introduced. There are, however, a number of general conclusions that emerge from past work that collectively reinforce the critical role of labor and its evaluation in assessing agricultural sustainability. Bojo's (1992) review of cost-benefit analyses of soil and water conservation in developing countries concludes that social profitability tends to exceed private profitability, largely because the social opportunity cost of labor is typically estimated to be lower than the market wage used in private profitability studies. Since conservation agriculture investments and subsidies are often justified on the basis of the creation of social benefits, both off-site and in the long-term, the valuation of labor is thus of critical importance in assessing the proper role for the public sector in promoting sustainable agriculture. Lutz, *et al.*'s (1994) assessment of soil conservation projects in Central America confirms that "adoption rates...correlate well with the estimated profitability of conservation" (although profitability is argued to be "a necessary but not always sufficient condition" for adoption). The centrality of profitability is also cited by Reardon (1995) in his review of conservation investments in sub-Saharan Africa, and the opportunity costs of household labor are noted as a key determinant of profitability. Current, *et al.*, (1995), reviewing agroforestry projects in Central America, find that farmers prefer less-intensive to more highly-intensive agroforestry technologies since the former can be scheduled for slack periods of labor demand, can be adopted incrementally and gradually, and the associated costs and risks can be spread out over time. Similar conclusions are demonstrated by McIntire, 1994, and Lutz, *et al.*, 1994, for soil conservation practices.

Economic evaluations of LEISA technologies, in general, and of the returns to labor, in specific, are hampered by a number of conceptual hurdles that make these evaluations difficult. These challenges include: measuring physical soil degradation and enhancement effects over time; the choice of discount rates in valuing future costs and benefits; the estimation of the off-farm vs. on-farm incidence of costs and benefits; and determining the shadow value of labor (Bojo, 1992; Lutz, *et al.*, 1994). Since a number of these issues involve valuation in the presence of spatial and temporal externalities in which social benefits may accrue in the future and/or off-site, estimates are inevitably prone to varied interpretations. While these challenges in measurement and estimation must be acknowledged, their existence is not a reason for failing to conduct these assessments to begin with or for disregarding the results. On the contrary, it can be argued that basic economic feasibility analysis should be considered as a prerequisite for investing in projects and programs promoting specific technologies. Kuyvenhoven and Ruben (1999) outline some of the economic appraisal options and the circumstances under which they can be employed.

In assessing the role of labor requirements and labor costs in LEISA practices, a number of issues recur both in practice and as reported in the literature. The remainder of this paper briefly identifies and discusses some of these key issues encountered in the analysis of agroecological systems.

Complementarity of Labor and Off-farm Inputs

In seeking to lower the dependence of farmers on purchased off-farm inputs such as fertilizers and pesticides – which, in some cases, contribute to adverse environmental outcomes – agroecology proponents commonly promote alternatives which are often intensive in the use of labor either in terms of establishment and/or maintenance requirements. Yet, it is a mistake to view labor and non-labor inputs fundamentally as substitutes. Rather, "labor productivity can be increased substantially when internal farm household inputs [e.g. labor] are combined with selectively applied external inputs" (Ruben and Lee, 2000). In large part, this is because increased soil nutrient levels will only effectively generate increased yields once threshold levels of *complementary* inputs are reached. The availability of labor is mainly required to guarantee the efficient uptake of nutrients during different phases of the plant growth process. The evidence of this is extensive in the biophysical literature (de Wit, 1992; van Keulen, 1982).

In the economic literature, as well, there is widespread evidence of input complementarity. Savadogo, *et al.* (1998) show that animal traction is West Africa is labor-augmenting and demonstrate the existence of "significant interaction effects" between manure and labor inputs under most conditions. Shepherd and Soule (1998) demonstrate the positive interaction effects of improved management of crop, cattle and forest resources in simultaneously generating higher farm profits, increased soil organic matter and low nutrient losses among farmers in western Kenya. Ehrenstein (1999) shows how crop residue mulching, making selective use of herbicides, can alleviate crop management bottlenecks through factor substitution effects, and how low applications of nitrogen fertilizer and selective mechanization can improve input use efficiency though interactions with crop residues, mobilization of complementary soil nutrients and water conservation. Reardon (1995), assessing investments in soil conservation in Africa, states that these investments "both compete with and are complementary to" productivity-enhancing investments requiring off-farm inputs, and urges the use of "overlap technologies" which combine conservation goals with productivity enhancement. In short, LEISA technologies and practices, while at one level substituting for purchased inputs, at another level, *complement* those inputs by generating higher yields and higher factor productivity.

Seasonality

Seasonality is relevant to the development of agroecological practices in at least two important ways. First, attention to sustainable agriculture concerns in marginal areas at least partially redresses the historical inattention to traditional crops and cultivation practices relative to industrialized country and Green Revolution agriculture. Progressive abandonment of "secondary" food and subsistence crops areas -- coarse grains, roots and tubers, pulses, tree crops -- that are of particular importance to the food security of small-scale, often subsistence-oriented agriculturalists in marginal areas has been stated to have exacerbated seasonal variability in food supplies (Longhurst and Lipton, 1989). To the extent that attention to agroecological concerns associated with secondary crops results in increased productivity of these cropping systems, seasonal variability in production and food security should be ameliorated.

The second effect, however, is less auspicious. Seasonality of production is associated with seasonality of agricultural labor market variables – incomes, employment, and wages -- a fact that has been widely documented across a range of developing countries (see review by Alderman and Sahn, 1989). This has at least two important implications. First, the shadow values of labor which are used in economic feasibility studies must not simply reflect average labor values; otherwise, they may not fully reflect actual seasonal labor scarcity at the time labor is required for labor-intensive activities. Second, although over the course of a year labor may be in surplus, it may be scarce at crucial times during the cropping cycle (Fafchamps, 1993), making reliance on labor-intensive practices more difficult or impractical for the farmer. Numerous analysts (Feder *et al.*, 1985; Low, 1993) have noted seasonal labor constraints in the adoption of LEISA technologies. Recognizing and accounting for these constraints in evaluating labor-intensive LEISA technologies, particularly those that require additional labor inputs.

Household Time Allocation

Most studies on low external input technologies generally assume that family labor is abundantly available. This assumption tends to be based on the observation that not all family labor force is employed full-time in productive and remunerated activities. However, it is far too easy to conclude from this that the household labor force can thus be mobilized for farming systems intensification.

Detailed studies on labor use in rural communities reveal that direct farm work accounts for only 20-40 percent of total labor time, even under subsistence conditions (Netting, 1993; Ellis, 1993). Other activities like household work (child care, housekeeping, firewood and water collection), non-farm work (handicrafts, commerce) and social obligations are often equally or more important in term of household labor allocation. Moreover, due to insecure market and tenure conditions, small farmers may have to commit part of their labor time to other agents in order to guarantee access to land, finance and inputs in facilitating their own production (Crow and Murshid, 1993).

The introduction of agroecological practices requires that farmers are willing to allocate time to their establishment and maintenance. Soil conservation activities that require mostly off-season labor and that otherwise fit into slack periods of labor demand are therefore generally more feasible. Willingness to work is also related to adjustments in the complex division of labor between gender and age. Sachs (1996) shows that organic pest and disease control technologies that rely on indigenous female knowledge are most advantageous to farmers.

Off-farm Labor Opportunities

Off-farm and non-farm employment opportunities for farm household members can have a critical effect on the opportunity costs of labor and, accordingly, can influence the economic feasibility of low external input technologies and the extent of their dissemination. This is likely to be an issue especially in peri-urban regions and other areas where significant incentives for alternative employment exist, yet there are many examples from relatively isolated areas as well, particularly where seasonal migration patterns are an established part of the household livelihood strategy. Fujisaka (1994) states that a major reason for farmer non-adoption of contour hedgerows in the Philippines was the existence of off- and non-farm employment work opportunities. Facing these opportunities, farmers modified recommended practices, cutting nearly in half the labor requirements for establishment of fodder hedgerows. Neill and Lee (2000) document farmer disadoption of velvet bean cover crops in northern Honduras, in part due to the improved road and transportation infrastructure, which improved farmers' accessibility to urban areas and increased employment opportunities and the opportunity costs of labor, making the maize-velvet bean system relatively less economically attractive to producers. (Alternatively, Ruben and van den Berg (2000) show that access to off-farm income may provide more purchasing power for increasing input intensity in agriculture). Lines (1998) shows how the proximity of urban labor markets in the Bolivian Altiplano affect labor availability, local migration patterns and the opportunity costs of raised bed agriculture – in this case, rendering this technology non-economical under most reasonable economic assumptions. Assessing conservation agriculture investments in Africa, Reardon (1995) concludes that the attractiveness and profitability of these investments compared to off-farm opportunities is a critical determinant of their adoption. In sum, farmers trade off investments of their time not only within agricultural alternatives but off the farm as well. In order to be successfully disseminated, those sustainable agriculture investments which intensively use labor must compete effectively with these other alternatives, both off-farm and non-farm. Non-farm alternatives, in particular, are often ignored in the promotion of sustainable agriculture technologies.

Technology Adoption

The traditional literature on the adoption of Green Revolution technologies has been increasingly complemented in recent years with growing evidence of the factors (economic, biophysical, demographic, institutional) that are associated with the adoption of low external input technologies. This literature has provided increasing evidence of the critical role of labor market variables (supply, demand, costs, seasonality) in influencing the adoption of these technologies. For example, variables representing the family labor supply (typically proxied by family size) are often shown to be significant determinants of sustainable technology adoption (Polson and Spencer, 1991; Neill and Lee, 2000). Available labor is typically positively associated with adoption, especially where the technologies are labor-intensive. The existence of off-farm employment alternatives as expressed by distance from farm to the nearest city or market is also often shown to be a significant determinant of adoption, with greater distance to market (and lower opportunity costs of labor) positively associated with adoption (Neill, 1998; Tessari, 2000). Economic and cultural factors related to labor migration also frequently play a role in technology adoption (Polson and Spencer, 1991; Neill, 1998).

Conclusions and Recommendations

The growing interest in and promotion of agroecological solutions to increasing smallholder farm productivity has highlighted the yield-increasing potentials of these technologies and practices, as well as agronomic and farmer organizational concerns, but often at the expense of criteria emphasizing economic feasibility and returns to scarce factors. This limitation must be addressed in the future work of researchers and practitioners in at least four ways. First, general economic evaluations and assessments of labor-market characteristics -- such as the labor demands of given LEISA technologies, their timing, local labor supplies, substitutability vs. complementarity with purchased inputs, seasonality, household time allocation patterns, and off-farm employment opportunities -- must be given a much more prominent place in agroecological analysis. Second, the heterogeneity of labor requirements for LEISA technologies suggests that *ex ante* estimation of economic returns to labor inputs -- and economic assessments of LEISA systems in general – should be a requirement of applied development projects *before* the promotion of these systems among farmers. Third, practitioners and policy-makers promoting agroecological practices should take greater advantage of the economic evidence that exists regarding LEISA technologies – for example, the documented role of profitability criteria in farmers' decision-making, and the considerable evidence farmers often prefer less intensive technologies that are more flexible, less risky, and that can fit into the agricultural calendar. Finally, agroecological analysis must additionally highlight the role of improved management of farming systems in optimizing the use of labor and non-labor inputs. This suggests – notwithstanding the declining state of many national extension services in developing countries – the continuing need for effective and innovative extension, farmer education and information delivery systems that can be useful to and used by farmers seeking to improve agricultural productivity. In sum, truly putting “farmers first” means devoting much greater attention to the use, value of and returns to farmers’ *time*, ultimately their most important resource.

Table 1. Examples of low external input agricultural technologies and practices

Soil Conservation

- Live barriers & hedgerows
- Bunds and ridges
- Ditches
- Conservation tillage
- Contour farming
- Alley cropping
- Terraces
- Mulches and cover crops
- Silt traps and gully fields
- Wind shields

Pest and Disease Management

- Use of resistant varieties and breeds
- "Natural" pesticides
- Bacterial and viral pesticides
- Pheromones to control reproduction
- Release of predators and parasites
- Beetle banks and flowering strips
- Rotations and multiple cropping
- Polyculture systems
- Improved weed management

Integrated Plant Nutrition

- Improving fertilizer efficiency
- Legumes and green manures
- Livestock manures and composts
- Crop residue management
- Improved fallow management
- Agroforestry systems

Water Management Systems

- Water conservation and harvesting
- Drainage
- Raised beds
- Microclimate management
- Fish production in irrigation water

Source: Thurston, *et al.*, 1992; Altieri, 1995; Pretty, 1995.

Table 2. Estimates of Labor Requirements for LEISA Technologies.

Technology/Practice	Country	Labor requirements (man-days/ha/yr)	Reference
Hedgerow (estab.)	Philippines	6-29	Fujisaka, 1994
No-till cultivation (maize)	Costa Rica Nigeria	30 58	Melendez et al, 1999 Ehui, *et al.*, 1990
Live barriers	El Salvador	40-43	Wall, 1981*
Weed management	Philippines	44-51	Moody, 1987
Organic vegetable production	Indonesia	47	van Elzakker, *et al.*, 1992
Taungya agroforestry	Central Amer.	53	Current, *et al.*, 1995
Alley cropping	Central Amer.	56	Current, *et al.*, 1995
Hillside ditches w/vegetation	El Salvador	84-143	Wall, 1981*
Fanja juu terraces	Kenya	107 136-281 150	Pagiola, 1994 Wenner, 1980 Barrett, 1985
Contour planting (trees and shrubs)	Central Amer.	116	Current, *et al.*, 1995
Alley-cropping (maize) (maize/beans)	Nigeria Tanzania	126-151 190-254	Ehui, *et al.*, 1990 van Elzakker, *et al.*, 1992
Mulching w/multi-purpose trees (maize)	Nigeria	134-202	Kormawa, *et al.*, 1999
Bench terraces (estab.)	El Salvador Burkina Faso Jamaica Java, Laos Indonesia	238-283 350-450 496 500-530 750-1800	Wall, 1981* de Graaff, 1996 Sheng, 1986* Fujisaka, 1994 Barbier, 1988*
IPM (rice)	Java	723	van den Fliert, 1993
Stone terraces	Peru	1181	Alfaro-Moreno, 1980*
Integrated agroforestry-soil conservation system, incl. tree planting	Vietnam	1500	Stocking & Abel,1992

* cited in Stocking and Abel, 1992.

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