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AGROFORESTRY IN DEVELOPING COUNTRIES

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AGROFORESTRY IN DEVELOPING COUNTRIES:

SELECTED POLICY ISSUES

by

Kenneth H. Shapiro

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AGROFORESTRY IN DEVELOPING COUNTRIES: SELECTED POLICY ISSUES

by

Kenneth H. Shapiro

This is one of four parts of a paper submitted to USAID under contract OTR-0091-C-00-2164-00. The other parts are: Microeconomic Aspects of Agroforestry; Sociocultural Aspects of Agroforestry with Special Reference to Adoption of Innovations; and Quantifying and Classifying the Benefits and Costs of Agroforestry. This policy section is based partly on the other three sections and partly on the literature. The following topics are covered: (1) definitions; (2) objectives; (3) dealing with diversity; (4) a systems approach; (5) subsidies; (6) property rights; (7) private and communal approaches; (8) farmer/government relations; (9) agroforestry research; (10) summary.

1. Definitions

For the purposes of this paper, agroforestry is defined broadly as those farming systems in which farm resources are allocated to raising crops as well as trees, either simultaneously or sequentially. Several elements of this definition warrant expansion. First, the focus is on farming systems, which implies some degree of integration among its elements and also some continuity. Second, farm resources are considered to be primarily land and labor, although cash costs also may be important. The word crops is taken to mean those plants usually considered as part of the farm enterprise while trees

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are not always so considered. Tree crops such as rubber and cocoa may fall in both categories, but the focus of recent attention and of this paper is on trees raised primarily for nonfood products. Finally, with regard to sequencing, agroforestry systems may involve crops and trees grown simultaneously on different plots or interplanted on the same plot, and they may involve crops and trees grown sequentially in rotation on the same plot. Thus the net is cast widely. A major exclusion is the large number of afforestation or reforestation projects undertaken primarily by governments without direct farmer involvement.

Definitions are often troublesome and at times their greatest value is only realized when there are divergent definitions of the same term. This is true in the present case where different definitions reveal different concerns and objectives. The definition offered above is intentionally broad because the concern here is with the use of trees by farmers in the process of economic development. How can or must trees be integrated into the farm enterprise to facilitate economic development?

ICRAF's 1978 definition differs in interesting ways (King, 1979, p. 1):

> Agroforestry has been defined as a sustainable land management system which increases the overall yield of the land, combines the production of crops (including tree crops) and forest plants and/or animals simultaneously or sequentially, <u>on the same unit of land</u>, and applies management practices that are compatible with the cultural practices of the local population (quoted from King and Chandler, 1978).

King elaborates on this definition as follows (Ibid., pp 1-2):

> You will note that by the addition of the phrase "on the same unit of land" we sought to emphasize that zonal arrangements of agricultural crops and forest crops were not considered to be agroforestry, and to imply that the mixtures of the agricultural and forest crops should be intimate.

King then goes on to define such intimacy in terms of the maximum widths of the rows of alternating agricultural and forest crops.

The strong biological orientation of this definition is revealed not only in the insistence on one unit of land but also in the focus on sustainability and in calling agroforestry a land management system. To an economist, sustainability[1] is but one out of many possible types of time paths for the accrual of benefits. In some cases it may be desirable to extract large benefits quickly and then abandon the site for some time or maybe forever. Sustainability is echoed in the emphasis on land management with no reference to labor or cash inputs.

The 1982 ICRAF definition bespeaks a somewhat broader view although the biological thrust still seems strong (Lundgren, 1982, p. 1):

> Agroforestry is a collective name for land use systems in which woody perennials are deliberately grown on the same piece of land as agricultural crops and/or animals, either in some form of spatial arrangement or in sequence. In agroforestry systems, the woody component interacts ecologically and economically with the crop and/or animal components. Such interactions . . . need not remain stable over time. (emphasis added)

[1]Here we assume that sustainability refers to a fairly constant steady flow of output.

The FAO (1978/p. 1) definition of Community Forestry, in contrast, is very broad:

> Community forestry has been defined for the purpose of this study as any situation which intimately involves local people in a forestry activity. It embraces a spectrum of situations ranging from woodlots in areas which are short of wood and other forest products for local needs, through the growing of trees at the farm level to provide cash crops and the processing of forest products at the household, artisan, or small industry level to generate income, to the activities of forest dwelling communities. It excludes large-scale industrial forestry and any other form of forestry which contributes to community development solely through employment and wages . . .

This FAO definition is perhaps even broader than our own in that the FAO does not seem to limit its field to farming systems but rather considers communities and includes small scale industrial activities. By limiting the focus to farming systems, the range of issues covered in this paper is somewhat narrower than that possible under FAO's notion of community forestry. On the other hand, by considering a very wide range of ways in which trees may be integrated into farming systems, the definition offered here may be somewhat broader than ICRAF's definition of agroforestry.

2. Objectives

A brief consideration of the various objectives of agroforestry may help to "flesh out" the above discussion of definitions. At least five broad objectives can be identified. Many times several objectives are served by the same type of agroforestry

undertaking, but there are also many cases in which one objective is clearly dominant. Five common, general objectives are:

(1) improving agricultural production[1]--e.g., shelterbelts, and interplanting leguminous tree species on cropland;

(2) improving forest production--e.g., taungya-type systems;

(3) protecting or improving the environment--e.g., tree planting to decrease runoff and erosion;

(4) increasing energy supplies--e.g., fuelwood plots;

(5) creating a local industry--e.g., raising trees that yield exploitable resins or gum arabic, or that facilitate silk culture or beekeeping, or that can support a sawmill.

This simple listing of objectives raises several interesting issues. First, obviously, is the diversity represented above. Agroforestry is multifaceted not only in its operational characteristics as indicated in the definitions but also in the nature of the benefits it can generate. Second, the different objectives tend to fall into the domain of different specialists and different ministries. Many governments have separate organizations to deal with each of the five objectives--agriculture, forestry, environment, energy, and industry. Third, the different objectives imply different client groups and different mixes of private and public goods and hence different decisions about government's role and subsidies.

[1]Including livestock production.

Finally there are obvious trade-offs between some of the objectives. For example, different management practices may be called for in maximizing value as a shelterbelt as opposed to value as a fuel source. The "joint product" nature of agroforestry is clear.

3. Dealing with Diversity

The above discussion brings out a major problem for a development agency concerned with agroforestry--great diversity. The brief review of definitions and objectives reveals a very wide range of activities calling for different skills and strategies, facing different types of constraints, and serving different ends. How can policy be formulated for such diversity?

One approach to dealing with diversity is to seek out those elements that all or most of the diverse activities have in common. The wide range of activities bearing the agroforestry label have several important common elements. Most obvious is that they all involve trees and farmers. Much of the technical expertise must be drawn from forestry whereas most of the economic and social considerations and some of the technical considerations are those of the traditional small farm. Another important commonality is that in many parts of the world many aspects of agroforestry are new and hence there is a need to develop or modify institutions, research, expertise, and attitudes. A third commonality is the systems emphasis, and, somewhat related to this, the fact that trees often provide several different types of benefits under agroforestry. These

considerations probably indicate a multidisciplinary approach. A fourth feature common to many agroforestry activities is small scale. This has implications for the nature of the funding and delivery agencies as well as for the relationships of agroforestry to other projects.

Another approach to dealing with diversity is to maintain a flexible, open approach. Institutions concerned with agroforestry should be able to recognize and service the needs for many different kinds of activities, or those institutions should have good communication with other bodies that can supplement in-house capacity. The merits of this approach should be balanced against an institution's developing strength in one or two types of activities such as fuelwood or shelterbelts. While specialization often facilitates expertise, it may also engender too narrow a view and the tendency to prescribe too few possible remedies for a wide variety of problems.

4. A Systems Approach

Perhaps more than most agricultural activities, agroforestry calls for a systems approach. In many cases, tree-growing is not profitable if the only benefits are wood, fruits, nuts, and so forth. There must also be benefits realized through the farm's crop and livestock activities such as in the case of shelterbelts, soil enrichment, and fodder production. Other linkages may arise through the labor economy if, for example, fuelwood plantings decrease wood

gathering requirements. The time saved can be used to increase crop or animal outputs. There also may be benefits derived if trees increase honey production, game populations, and other natural phenomena.

The systems emphasis in agroforestry naturally calls for consideration of the relevance of farming systems research (FSR). FSR has almost as many definitions as agroforestry, but the following by Shaner, Phillip, and Schmehl (1982, pp. 13-14) would probably be widely accepted:

> FSR&D[1] is an approach to agricultural research and development that
>
> - views the whole farm as a system
> - focuses on (1) the interdependencies between the components under the control of members of the farm household and (2) how these components interact with the physical, biological, and socioeconomic factors not under the household's control.

Shaner, et. al. (1982, pp. 14-15) distinguish the farming systems approach from conventional approaches as follows:

> FSR&D looks at the interactions taking place within the whole farm setting and measures the results in terms of farmers' and society's goals. Traditionally, conventional research separates tasks into progressively narrower subject areas to be studied more or less independently and then evaluates results by standards within the discipline, not by their contribution to the whole.

FSR typically calls for an iterative approach with on-farm trials. The long growth period for trees calls for special

---

[1]The "D" stands for development.

adaptations if FSR is to be used in agroforestry. Gilbert, Norman, and Winch (1980, p. 11) propose four stages of FSR:

(1) The descriptive or diagnostic stage in which the actual farming system is examined in the context of the "total" environment--to identify constraints farmers face and to ascertain the potential flexibility in the farming system.

(2) The design stage in which a range of strategies are identified that are thought to be relevant in dealing with the contraints delineated in the descriptive or diagnostic stage.

(3) The testing stage in which a few promising strategies arising from the design stage are examined and evaluated under farm conditions. This stage consists of two parts: initial trials at the farm level with joint researcher and farmer participation, then farmer's testing with total control by farmers themselves.

(4) The extension stage in which the strategies that were identified and screened during the design and testing stages are implemented.

The schematic representation of these stages shown in Figure 1 stresses the iterative nature of FSR.

The International Council for Research on Agroforestry is pursuing a program of "Agroforestry Systems Research and Evaluation" which has a strong FSR orientation. A schematic representation of the ICRAF approach is seen in Figure 2.

Because most trees take a long time to grow and have a long life span, it is often impossible to follow the FSR iterative field trial approach. To deal with this problem, ICRAF is developing simlulation programs to show the effects of different agroforestry systems over long time periods. A combination of such computer simulations and on-farm trials is useful.

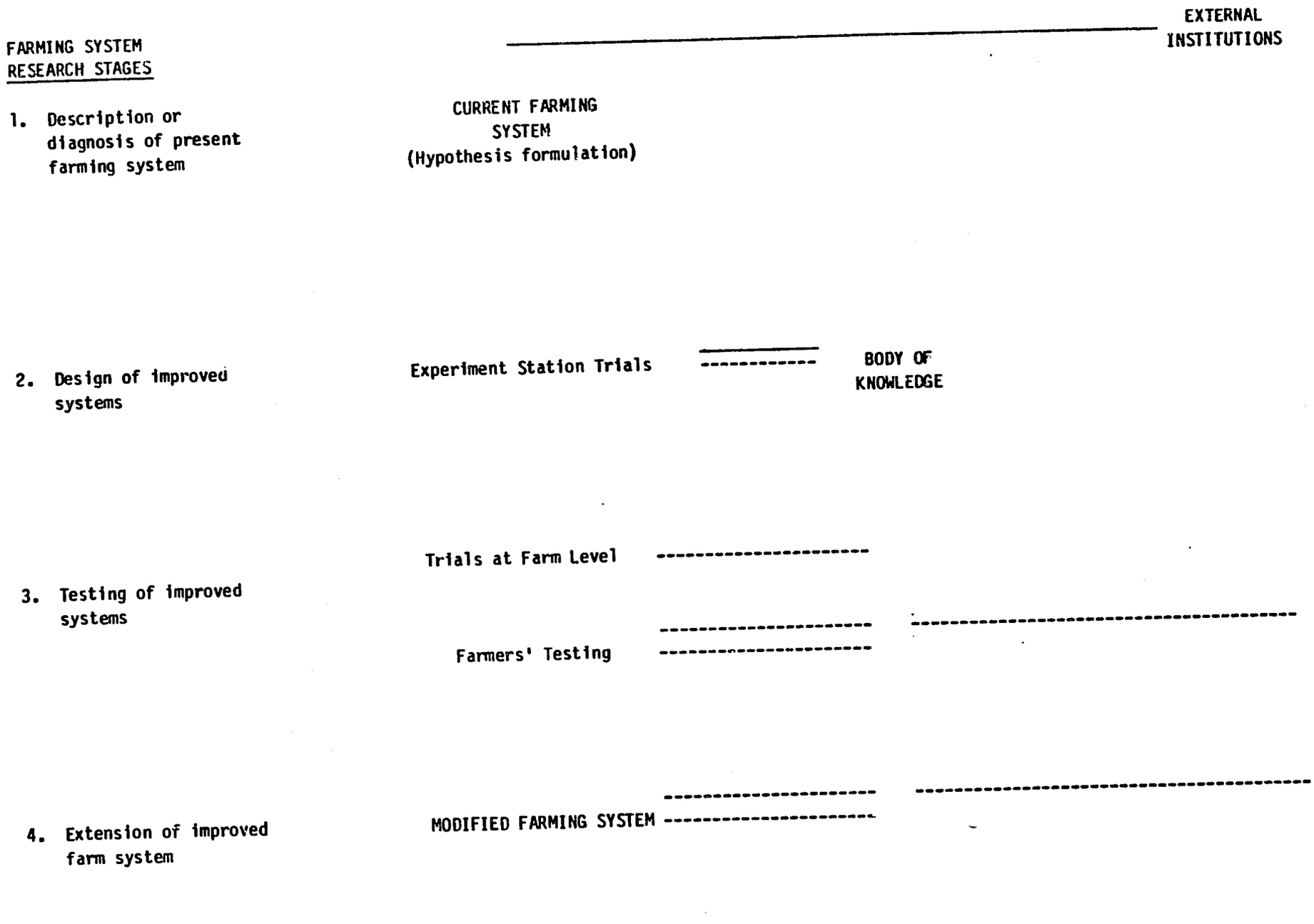

Figure 1. SCHEMATIC FRAMEWORK FOR FARMING SYSTEMS RESEARCH AT THE FARM LEVEL (Downstream Farming Systems Research)

Source: Gilbert, Norman, Winch, 1980, p. 12.

In general the use of a FSR approach to agroforestry planning seems to make sense and is already underway.

5. Subsidies

As indicated above, agroforestry is often characterized by several outputs or benefits accruing at various times and places and caputred by different individuals. The need for subsidies arises when society wishes to produce certain benefits that are not captured by the farmer or to which the farmer applies too high a discount rate. For example, the downstream effects of watershed protection upstream are not captured by farmers living upstream. Another example is the soil conservation benefit that occurs so far in the future that farmers count its present value as almost nil but which governments, with a low social discount rate, might value more highly.

Kunkle (1978, pp. 17-18) provides several estimates of the downstream value of watershed management. For example, a conservation program at the Poza Honda basin in Ecuador would slow sedimentation and thus extend the reservoir's life by 25 years. This is estimated to yield $2 million of benefits per years and have a cost of only $1 million. Numerous examples such as this make it clear that in many cases there is ample justification for substantial subsidies to agroforestry activities.

The background paper on "Microeconomics of Agroforestry" submitted with this paper discusses alternative mechanisms for including so-called externalities in benefit/cost analysis. As shown

there, even if a precise value for, say, downstream benefits, cannot be determined, there are ways to incorporate such external benefits into the analysis.

While one may accept the general principle of using subsidies where external benefits exist, the nature of the subsidy warrants close examination. In a discussion of erosion control in Haiti, Murray (1980, p. 9) refers to numerous projects in which trees were planted or stone walls constructed with coercion or with payment to farmers.

> "The trees planted, or the rock walls built, under these circumstances, rarely survive, even when placed on marginal land. This latter type of land is used for the grazing of animals. When the trees have been planted, the walls built, and the wages collected, animals are let back into the field. And then, in the words of the peasants, . . .the cow's mouth eats the seedling, its feet destroy the wall. The result has been the destruction, in most project regions, of probably more than 75% of the trees that were planted and perhaps 90% of the walls that were built."

The obvious lesson from such experiences is that subsidies at the establishment phase make sense only if the costs of continued maintenance (protection, watering, opportunity cost of land) are outweighed by the benefits to the farmer. More generally, subsidies must be large enough so that the unsubsidized costs to the farmer are less than his benefits otherwise the farmer will not incur those costs. If external benefits do not justify such subsidies, then the

undertaking is not worthwhile from a social as well as a private perspective.[1]

Murray proposes an alternative approach to subsidies--offering innovations that are profitable to farmers but which require the desired conservation activity as a production input. The example he studied was bench terracing as an element of cash vegetable farming on Haitian hillsides. For agroforestry the linkages are often tighter. The planting and maintenance of trees will occur if farmers receive reasonably short-term net benefits such as those derived from fruits, honey, fuelwood, and so forth. Murray (Ibid., p. 49) contrasts this profit oriented approach with one that

[1]Designate Total, Private (farmer's), and External Benefits as TB, PB, and EB respectively; and Total, Private, and External (subsidized) Costs as TC, PC, and EC respectively all in present values. A project should be undertaken if

(1) TB > TC or (2) PB+EB > PC+EC

The above discussion by Murray indicates that after subsidies, the private benefits must exceed the private costs, or, at the limit, be equal. Thus the minimum subsidy is one that brings PC down to the point where PB=PC. These terms can thus be removed from (2) leaving the following decision criterion:

(3) EB > EC*

where EC* is the minimum subsidy possible.
Inequality (3) states that external benefits must exceed the subsidy when the minimum possible subsidy is given. If the minimum subsidy is greater than the external benefit, the project is socially not worthwhile.

On the other hand, if more than the minimum subsidy is given, EC can exceed EB so long as that difference is less than PB-PC, the private net gain. That is, a project is worth undertaking if EC > EB so long as PB-PC > EC-EB. This is the case of an income transfer to farmers. The reverse is also theoretically possible, but, according to Murray and others, not viable. That is, a project is socially worthwhile if PC > PB so long as EB-EC > PC-PB. However, this is an income transfer from farmers to the rest of society and will not occur or persist without coercion.

> "calls on the motivational and educational expertise of donor agencies, that points to long-term benefits, to the obligation to work together as communities on projects which may have no immediate income implications, but which are for the general good of the community or for future generations."

In sum, based on the Haitian experience, he opts for profits rather than altruism. If subsidies can make an activity profitable to farmers, they should be considered subject to the limits discussed above.

6. Property Rights

The background paper on "Sociological Aspects of Agroforestry" submitted with this paper provides a detailed review of how agroforestry is affected by different rights in land and trees. That review provides a number of lessons for policy makers. The first is that such property rights are highly variable over even short distances. Second, rights in land and trees are often quite complex differing between ownership and use, and differing according to how the land or trees will be used. Third, these property rights are not static, and the history of their evolution may given clues to how they may change under new activities such as agroforestry. The implication of this diversity, complexity, and dynamism is that few, if any, *a priori* policy statements are possible for any locality. Detailed study is needed to understand local property rights and, more importantly, how those rights may change under new agroforestry activities. One can easily prescribe that farmers must have secure

rights to the benefits from trees they grow, or in a communal context, that those benefits accrue equitable to all participants. However, only detailed local study can operationalize such prescriptions. Cernea's (1981) analysis of the village commons in Pakistan provides a very good example of how an agroforestry project ran into difficulty because the complexity and dynamism of property rights were not fully explored. What appeared at first analysis to be common lands were indeed lands capturable by wealthy villagers.

7. Private and Communal Approaches

The background paper on sociological aspects highlights two issues: equity and ease of adoption. While communal approaches may be more equitable, they tend to be harder to bring about. Indeed, the difficulty found in encouraging all forms of communal agriculture engenders pessimism about a widespread communal approach to agroforestry.

8. Farmer-Government Relations

There are a number of reports from Africa and Asia of governments coercing or exploiting farmers in the promotion of agroforestry activities. For example, FAO's (1982) review of the Korean success under Saemaul Undong notes that (pp. 26,77):

> There is no question that participation was initially elicited through strong authoritarian government pressure.
>
> Whether these achievements were accomplished mainly through government mandate and pressure, through voluntary participation or a combination of both is open to question. Most likely it is a combination, with

> heavy government influence in the early part of the seventies and a gradual shift to voluntary village efforts during the latter years, as success became known to villages and benefits from forestry increased markedly.
>
> At the same time, there is no denying the fact that the changes brought about were not popular with all rural inhabitants. For example, the stringent requirements for private forest land management introduced in the 1972 Forest Development Law are undoubtedly considered to be negative by many land owners.

While the FAO report states that voluntary cooperation followed initial coercion in Korea, the future seems to be clouded (p. 82):

> Maintenance of the cooperative spirit and willingness to provide labor for no pay or below going wages for community projects is one of the major challenges facing the nation in the coming years. As incomes and standards of living rise, people are more and more reluctant to provide their time and efforts on a cooperative basis and without pay.

There seems to be a problem of villagers not perceiving sufficient personal benefit from the forestry activities. Thus the need for government coercion.

In China there are reports of intensive public education and motivation efforts by government, backed by regulations and punishment of "forest felons."

> Chairman Mao's thoughts on forestry and its interdependence with agriculture and animal husbandry, enunciated by him in 1958, have been disseminated to the masses through a system of mass communication . . ." (FAO,1978, p. 18).

The Chinese system of mass mobilization for community projects is probably not replicable in any other developing country.

In West Africa there are reports of the forest service playing a police role vis a vis farmers. For example, Thomson (1980, p.9) discusses the Niger case as follows:

> Tree tenure rights are defined by the Forest Service. Roving forest guards enforce national Forestry code regulations, often with less than strict regard to the letter of the law. Allegations of corrupt practice are frequent enough so that every village has a history of judicial contact with forest guards.

Another negative element is the exploitation reported in some government-run taungya systems. There are reports of government services in India, Sri Lanka, and Nigeria taking aoavantage of land shortages to employ farmers at less than minimum wage levels. FAO (1981, p. 35) describes Indian taungya as follows:

> The system is frankly exploitative in concept and operation and cashes upon the needs of the landless and poor people to serve its own ends. The much vaunted incen-incentives are only a cloak for uninhibited exploitation, as the savings effected by the Forest Department are many times more than the expenditure incurred on elementary conveniences provided to the working force.
>
> The taungya system as practiced in India is purely forest-oriented and exploitive in character. The elements of community development are rudimentary and the contribution of this technique to the enhancement of the living standards and quality of life of the rural poor is minimal.

The same FAO report writes of taungya in Sri Lanka as follows (p. 86):

> "It is not possible to conceive of the system as it is now practiced, as being socially acceptable, equitable, or just."[1]

[1] One might well argue that "surplus" labor has a minimal opportunity cost and that hence exploitation is hard to prove. However, one might expect governments to resist capturing all the surplus generated by such labor.

In southern Nigeria farmers entered taungya primarily because of the land shortage and their efforts were almost entirely for subsistence and not a cash surplus. Ball (1977) does not discuss expoitation, but does cite a tension between farmers and foresters as well as the need for closer supervision and fines for work that is not up to standard.

Reports of coercion and exploitation, such as the above, raise disturbing questions. Do they signify that in many areas agroforestry is not privately profitable? It is especially troublesome that these reports come from places and projects often held up as examples of successful agroforestry. Donor agencies will obviously want to avoid such negative aspects in any programs they support. But beyond this, the agencies might be aware that there is a history of farmers not willingly undertaking agroforestry.

Rather than turning to coercion, donors might consider the positive alternative of subsidies to make the activity privately profitable. If one assumes economic rationality by the relevant government agencies, then one might conclude that coercion was employed to garner benefits for others besides the coerced, who did not perceive the prospect of sufficient benefits. Those others might be farmers using irrigation downstream, or city dwellers relying on hydropower from a dam that is silting up, or future generations in the immediate area. If benefits to others are real, then income transfers from those others to the coerced agroforesters would be justified.

9. Agroforestry Research

Agroforestry research can be discussed in a number of contexts. This section confines the discussion to the relation between agroforestry research and (a) Farming Systems Research; (b) ICRAF; and (c) the International Research Centers. USAID is active in all three.

Farming Systems Research (FSR) has made two contributons to agricultural development research. First, FSR reminds us to look at the entire farming system including production, consumption, cropping, animals, and the natural environment. Interactions and feedback loops are emphasized as much as the individual elements. Second, FSR usually underscores the value of learning from the farm and farmer. This is important in setting research priorities and in evaluating innovations.

As discussed in Section 4, the systems orientation of FSR is obviously relevant to agroforestry. Introducing trees to the farm places greater demands on land and labor, and this may imply decreases in other farming or nonfarming activities. The value of the trees may lie not only in its major products (e.g. firewood) but also in erosion control, nitrogen fixation, and so forth. Finally, agroforestry may decrease fuelwood collection time so much that there is a net gain in labor available to the farm.

Three aspects of FSR are not conducive to agroforestry research. First, most FSR has a short run orientation in both its

methodology and its pay-off horizon. For example, Norman and Gilbert (1981, p. 21) write as follows:

> Downstream FSR programs, which are the main concern of this paper [and of most practitioners], have an adaptive orientation and aim at developing and introducing strategies that will improve the productivity of farming systems for target groups of farming families in the short run.

Second, FSR has also emphasized short-run methodologies. Although not completely eschewing year-long, repeat interviewing approaches, most practitioners seem to prefer rapid surveys during one or several parts of the year. Because fuelwood collection is a regular activity, often occurring through most or all pf the year, the year-long repeat interview method may be important to pinpoint labor conflicts. This approach is especially important if the success of the agroforestry project depends on the productivity of labor freed from fuel collection. In such cases, the planner must be able to estimate the marginal productivity of such labor applied to crops or other activities. This estimation implies analysis of production functions which requires accurate, detailed labor data over long periods. Although FSR does not exclude such data collection methodologies important to agroforestry research, it tends to downplay them.

A third aspect of FSR that may not be conducive to agroforestry research is the crop orientation of most FSR to date. Efforts are underway to deal more explicitly with animals now, but forestry activities have not been dealt with intensively. Thus, while FSR certainly can deal with agroforestry, most practitioners have

not. Hence, the peculiar methodological issues inherent in trees have not been addressed by most workers. A major exception is the previously mentioned work underway by ICRAF.

The International Council for Research on Agroforestry (ICRAF) is adopting FSR for use in agroforestry work. In their "Programme 4, Agroforestry Systems Research and Evaluation," ICRAF has established four projects related to FSR: (1) Diagnostic Methodology; (2) AF Systems Inventory and Evaluation; (3) AF Systems Modelling; and (4) Methods to Assess AF (ICRAF, 1982, p. 35). As the project titles imply, this ICRAF program includes rapid reconnaisance efforts at the diagnostice stage and longer-term involvements at the design and evaluation stages.

ICRAF offers at least three important advantages for agroforestry research. First, it is a center of expertise about trees. Second, it is intended as a "permanent" institution which means it can undertake programs that cover the lifespan of many tree species. Third, its international orientation facilitates borrowing information and experience.

ICRAF conducts only limited biological research itself. Ideally, ICRAF would work with the International Agricultural Research Centers which already have operational farms, laboratories, and field research programs. Agroforestry programs could be integrated into these, with ICRAF helping set the priorities and providing backstop expertise on the trees.

10. Summary

Agroforestry has been practiced in various forms for centuries. Its scientific study is much more recent, and economic analysis of agroforestry is in its infancy. Thus this literature review may have been somewhat premature. Biological questions have received the most analytical attention. Socioeconomic issues have thus far been treated primarily in a descriptive manner, and even this is somewhat limited with very few studies covering periods from tree planting through maturity. Most economic analyses have been standard benefit/cost exercises, but there have not been enough to draw generalizable lessons. Indeed, since most authors emphasize the site-specificity of results, there may be few generalizable lessons to draw.

Given the relative youth of this field, the more important policy issues may involve research and general approaches. Some of these are covered above. More detailed issues in the literature are covered in the other three papers submitted.

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by

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SOCIOLOGICAL ASPECTS OF AGROFORESTRY

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Patrick West

INTRODUCTION

It has now become part of the conventional wisdom that sociological factors are among the key components in designing and effectively implementing agroforestry projects in developing nations (e.g. FAO, undated; World Bank, 1978; Noronha, 1980; Cernea, 1981). This paper seeks to summarize, in a useful form, what is known about key selected sociological factors, barriers, and strategies in agroforestry programs. The fundamental conclusion from practically all analyses conducted to date is that the traditional top-down, imposed approach to community agroforestry, so common in many early efforts in agroforestry, is simply not working. A more participatory approach in which the cooperation and direct involvement of local people is obtained is essential to success. And central to gaining this acceptance and involvement is the clear assurance that sufficient and equitable benefits will be received by local people from agroforestry projects initiated by AID or other donor agencies.

Throughout this paper particular findings from field research and project evaluation studies conducted specifically on agroforestry projects are supplemented with wider literature on relevant findings from broader rural development research. This broader approach is employed primarily to gain the advantage of insights from sociological research in other related natural resource and rural development settings that are applicable to agroforestry. This is especially important where key social factors have been studied more in other sectors (e.g. irrigation, grazing) than they have in the newer subfield of social aspects in agroforestry. While we must be cautious about the applicability of research findings from related areas, neither should we try to "reinvent the wheel" of rural agricultural development in the agroforestry sector.

The paper is organized topically by types of sociological factors or considerations such as participation, communications, equity, incentives, etc. However, it should be emphasized that no single factor will determine success or failure. Rather, it is the combination and interaction among factors that makes the critical difference in gaining the adoption and long-term success of agroforestry programs in developing nations.

THE NEED FOR PARTICIPATORY APPROACHES

Numerous analysts of agroforestry projects in different developing nations have converged on the central importance of locally based, participatory approaches to rural community agroforestry. Hoskins (1980, p. 156) in her review of African

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fuelwood for AID concluded that "it is increasingly apparent that the top-down approach is not working" and that more meaningful participation needs to be developed. This fundamental message is echoed by numerous others including Spears (1978, p. 4), Noronha (1981), Cernea (1981), Thomson (1977 and 1980a), Winterbottom (1980), and Brechin and West (1982). A number of these analysts have conducted within nation and/or cross-national comparative studies that tie success and failure directly to the presence or absence of participatory approaches. Noronha (1981) compares successful participatory programs in Korea and to a lesser extent in Gujarat, India, with imposed, nonparticipatory approaches that are not working, especially for village woodlots in Niger, West Africa. Various comparative studies within the African Sahel have drawn similar contrasts. Voluntaristic participatory programs in Senegal have succeeded far better than enforced participation elsewhere in Senegal and imposed top-down projects in Niger (Hoskins, 1980). Similarly, in a comparison of numerous agroforestry projects in the Sahel, Winterbottom (1980, p. 9) found that most village woodlot projects did not involve local communities and experienced high rates of failure. Most successful projects had a high degree of involvement and participation. Thomson (1980a) has compared the institutional barriers to participatory approaches in Niger, leading to widespread failure, with a more participatory approach in various successful projects in Upper Volta. Within Niger (which is emerging in numerous comparative studies as almost the "ideal type" of the top-down, heavy-handed approach to community level forestry), Thomson (1977, 1980a, 1980b, 1980c, 1980d, 1981a, 1981b.) has rigorously documented the political and bureaucratic roots of this rigid top-down forestry model which is stifling local initiative. However, within this institutional structure, variations were found by Brechin and West (1982). In one highly successful project in the Majjia Valley, the local forester sought to communicate with and involve local people while still operating within the imposed constraints of the authoritarian national forestry bureaucracy. In contrast, in a nearby county we found the following situation that illustrates the more typical situation in Niger.

> An autocratic forestry official with the aid of a Peace Corp volunteer went to survey a new location for a village woodlot. Upon arrival at the spot, the volunteer asked the official if he had notified the farmer and others about his plans. The official replied that everything had been taken care of. While the two continued to look over the area and discuss technical options, the farmer who worked the land came upon the two foresters and curiously asked what was going on. The official only then informed the farmer that his land had been selected for a woodlot project and the farmer would not be allowed to plant millet or other grain crops in the area. When the farmer spoke to protest, the official walked away. This particular

forestry official has held his position for over twenty years and yet is unable to boast of a successful project in his district (Brechin and West, 1980, pp. 90-91).

While the need for more communications and participation-oriented approaches seems clearly established, achieving this is another and far more difficult matter. Institutional and structural barriers such as those found in Niger are hard to change, and even where such national structural barriers are less prevalent or can be redirected, the problems of gaining local trust and effective local participation are formidable.

The first step must be a reorientation of forestry programs away from traditional enforcement approaches to a more communications extension model. But beyond this, the communications must be not simply communications to, but rather true communications with local people. This must involve not only cultural and needs assessments but also actual involvement and local control over project design, implementation and long-term management. In the following section we consider strategies for implementing effective local communications and participation.

COMMUNICATIONS/EXTENSION STRATEGIES

Retraining

Winterbottom (1980, p. 23) notes that the first and most fundamental change that is needed in many areas is to redefine the role of local forestry agency personnel away from an enforcement focus to an extension communications orientation. AID and other donor agencies now regularly include strong extension service communications components in agroforestry AID programs (e.g. USAID, 1979, p. 3). The institutionalization of this orientation in host country bureaucracies, through which forestry assistance is almost invariably channeled, has been slower in coming, but is starting to occur in many areas. In Gujarat, India for instance, forestry professionals now regularly receive training in communications, extension, and community relations (Noronha, 1980).

Some of these retraining efforts have met with more success than others. In the Kordofan region of Sudan, efforts to retrain forestry staff to an extension focus have been well received by most foresters there (Hammer, 1982, p. 58). In other areas, such as the Kombissiri area in Upper Volta, forestry extension workers were retrained in communications and participatory strategies but the training had little impact on entrenched behavior. Many continued to "discount the value of dialogue with villagers...contact with participating villages remains infrequent... [and] in some cases

they supervised planting activity as if it were little different from a small-scale 'industrial type' plantation and treat villagers as paid laborers" (Winterbottom, 1980, pp. 21-22).

This resistance in the face of retraining efforts presents a major barrier and challenge to effective communications. It indicates the need to give as much attention to strategies for educating the supposed educators, as we give to strategies for educating farmers and villagers. This task is addressed below in the section on bureaucratic reorientation.

Role Conflict

These problems are further complicated by the role conflict between forester's roles as "enforcers" and their growing role as "communicators". In Niger, where the enforcer role has been unusually harsh and sometimes predatory (Thomson, 1977), we observed particularly sharp role conflict creating ambivalence among villagers. "The villagers are often uncertain as to which hat the official is wearing and have no guarantee that the official will not switch hats" (Brechin and West, 1982, p. 90). Hoskins (1980, p. 158) makes the same observation elsewhere in Africa; Cernea (1981) observed similar role conflicts in community forestry programs in Pakistan; and Tucker (1982a) found the same problem in northern India.

Effect on Adoption

Nevertheless, effective programs of extension communications efforts have improved the success rates of agroforestry programs in many areas, for instance, in Labgar, Senegal (Hoskins, 1979, p. 166), and in the Koudougou, Bobo-Dioulasso and Hounde areas of Upper Volta (Winterbottom, 1980, p. 14 and 16). In the State of Gujarat, India forestry extension programs based on "extensive public information campaigns" have been more successful in gaining adoption of agroforestry project on larger farms than on smaller farms (Noronha, 1981, p. 6).

Communications Strategies and Needs Assessment

Numerous agroforestry project evaluation studies note the importance of effective communications and extension activities in the success of community forestry efforts, but little detailed assessment of specific, alternative communications strategies has been done. A recent FAO (undated, p. 49) publication noted that "little work has been done in rural forestry extension. General experience and techniques will have to be adopted for it."

This same publication proposes the use of mass media as a major strategy for "communicating" the forestry message. However, the broader literature on communi-

cations and rural development is fairly conclusive in its findings that the mass media are ineffective, especially in creating attitude and behavior change (e.g. Rogers, 1976; Rahim, 1976; Beltrans, 1976, p. 3) in comparison to strategies of personal contact and interpersonal social influence. The mass media also tend not to reach the poorest strata.

Romm (1978, p. 53) is careful to note that extension communications efforts must not be concentrated just on initial adoption. It must have continuing and long-term follow-up to help insure smooth long-term project management on a sustained yield basis.

The use of local opinion leaders to enhance the positive effects of interpersonal contact and social influence is now standard practice in many areas of rural development extension and communications efforts (Rogers and Shoemaker, 1971). The identification of local opinion leaders should be an important aspect of any preproject social assessment. However, it is important to identify and utilize opinion leaders from both upper and lower social strata groups if diffusion of agroforestry innovations through interpersonal influence is to reach the poorer strata, and thus help to avoid the differential adoption by large farmers noted above.

Another important strategy that can and should be adapted from standard rural development practice for agroforestry extension efforts is to go beyond the informal use of natural opinion leaders in the community and incorporate them more formally into the extension structure as indigenous paid extension agents. The development of an indigenous cadre of extension workers enhances the possiblity of successful innovation adoption. Peasants trained as local extension agents have several advantages: (a) they can bend messages to conform to cultural norms; (b) they can increase message credibility; and (c) they are able to relate better to local problems and conditions (Mani, 1974).

Most analysts focus on the problems of the long time and intensive training needed to produce cadres of effective indigenous village-level workers. It should be stressed, however, that a more important problem is building and maintaining "commitment" (Wava Haney, personal communication). Even when recruits are drawn from the strata one may wish to reach, their new status often engenders a new "class interest" that can lead to exploitive relationships. One way of helping to ensure commitment is to tie material rewards for extension personnel to clearly specified measures of program goal achievement, rather than simply creating a salaried class whose economic interests are independent of, or even opposed to real progress and improvement for the marginal peasant (John Lewis, USAID, personal communication).

Careful attention should also be given to the content of communications. As Noronha (1980, p. 6) cautions, "The project must be broken down into easily understood components which have the same meaning to the local participants as was intended in the project. For this, an understanding of the local idiom and sociocultural setting is necessary; meer translation of the English or French versions of the project will not suffice."

Needs Assessment

The most critical aspect of communications strategies, however, is that communications should not be viewed solely in terms of communications to local farmers and villagers, but rather in terms of communications with them. Winterbottom (1980, p. 14) found that forestry extension efforts that emphasized only communicated messages to local villagers (in contrast to a two-way flow of information in a participatory mode) was generally not as effective in gaining local support for agroforestry projects. Similarly, Hoskins (1980, p. 159) found that the failure to assess local felt needs in communication programs led to surface compliance in requests for labor contributions, but then to sabotage of the project because of conflict with felt needs to devote time to agricultural fields. This need for a participatory communications approach, involving especially "needs assessment", is now a generally well accepted critique of the old "targeted communications" model (e.g. Fett, 1974; Essman, 1974; Dandekar, 1972; Rao, 1972).

FAO (undated, p. 31) has stressed the importance of "needs assessment" in agroforestry programs, and numerous community forestry project now regularly incorporate this in preproject assessments (Noronha, 1980, p. 37; Hoskins, 1980, pp. 164-165). However, a caution is in order based on the experience of needs assessment studies in other rural development settings. As far as possible, the needs assessment should be detached from identification with any specific project or agency. Experience with needs assessment programs in Mexico suggest that peasants know what their needs are but also know what representatives of specific programs can offer. Thus as one field agent observed: "they ask for the things you have to offer, even if this has nothing to do with their real needs" (Grindle, 1977, p. 151).

Specific needs assessments that have included forestry among others have frequently found that agroforestry is not as high on local villagers' lists of priorities as other basic needs such as water, health, education, roads, etc. (Noronha, 1980, p. 37; Hoskins, 1980, pp. 166-167). Within the agroforestry sector the highly visible attention given to the fuelwood crises, and hence with fuelwood production, in donor-sponsored programs, is not as frequently seen as a felt need by local people although other

benefits of agroforestry may be more in demand (Hoskins, 1980, p. 177). This is especially true where fuelwood scarcity is not yet as severe, and fuelwood is still defined locally as a free good. Conversely, a felt need for wood stock management increases as scarcity increases (Thomson, 1980b, p. ii; Thomson, 1981a, p. 12). This seems to be especially true for women who bear the brunt in fuelwood-gathering labor (Hammer, 1982, p. 45).

This raises another problem, however, that traditional foresters might legitimately raise: people's felt needs are short-term and perhaps should not be relied on totally in project design especially for forestry which involves long-time frames. Nevertheless, the fact of a lack of felt need must be understood, and projects involving long-range rehabilitation and supply needs must be designed to motivate people in the face of this, or educate them to perceive a felt need if projects are to be accepted.

Despite this caution, needs assessment should go beyond general surveys of needs, and involve local people directly in the details of project design and implementation. In one successful program in Senegal, local people were educated about program options and potential consequences, and then were given control over detailed selection of program elements and work plans. The program succeeded in part due to detailed tailoring to local needs and perceptions (Hoskins, 1980, pp. 166-167). Where people can have some control over species planted, for instance, they can better meet felt needs, and have a greater stake in project outcome (Brechin and West, 1982, p. 91). In contrast, in one Upper Volta project, eucalyptus was planted as the preferred species by foresters without consulting the local people who rejected support of the project because they felt eucalyptus as a fuelwood adversely affected the taste of food (Noronha, 1981, p. 11).

However, extending the degree of local involvement completely to decentralized local control creates a very thorny problem that must be recognized and confronted. It is important to recognize and counter the tendency for decentralized programs close to the people to be "captured" and controlled by local vested interests. In India, for instance, the State of Rajasthan has carried decentralization of rural development administration farther than other areas, but its programs have been captured and redirected in the interests of local elites as a result of this decentralization (Berreman, 1967). Thus, a central dilemma and problem in devising effective participatory solutions is one of gaining decentralized access and responsiveness while avoiding excessive domination by local power elites.

Overemphasis on Communications

As important as communications, is, many analysts in the rural development field feel that communications, even two-way participatory communications, has been over-

emphasized. For instance, Felstehausen (1973) argues that a preoccupation with the communications extension model has led many assistance agencies to literally ignore other social and institutional structures and processes that can hinder or promote rural development. Similarly, Grunig (1971) argues that communications can have little impact unless accompanied by other structural changes. This argument is echoed by Heady (1965). This critique may also be relevant to agroforestry programs. It suggests that we need to give more attention to social and institutional barriers to the adoption and long-term management of agroforestry projects. In the following sections various village-level and extralocal social barriers to the effective implementation of agroforestry projects are discussed. These barriers, however, often differ by type of agroforestry project, particularly between individually adopted practices on a farmers' own land, and collective projects such as village woodlots. Thus, some preliminary discussion of the differential nature and problems of individual vs. collective agroforestry projects is needed.

COLLECTIVE VS. OPTIONAL ADOPTION[1]

Research on the diffusion and adoption of innovations has focused primarily on adoption by individuals or what Rogers and Shoemaker (1971, p. 269) have termed "optional decision making by individuals, rather than collective decision making within social systems." Collective adoption of innovations has received far less attention, yet it is an important component of rural development strategies in general (Katz, 1962; Kerr, 1970, p. 1; Rahim, 1968, p. 18; Rogers and Shoemaker, 1971, p. 269), and agroforestry development projects in particular. Rogers and Shoemaker (1971, p. 270) define collective adoption as "collective decisions, made by the individuals in a social system by consensus." Rahim (1968, p. 25) defines it more specifically as the adoption of an innovation by a collectivity in which "the decision to adopt is made jointly by the system's members and the actual use of the innovation involves joint efforts by the members of the system."

Some projects such as a school built by community effort cannot be optionally adopted by individuals. Most collective adoption projects, however, can be adopted either by individuals or by groups. Tubewells (Gotsch, 1972), collective agriculture (Coward, 1973, p. 240; Lele, 1975, p. 74), and fishing (Apthorpe, 1970; Ghee, 1978) can all be collectively or individually pursued.

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[1]The following discussion of collective adoption draws heavily on previous work reprinted from P. West's article "Collective Adoption of Natural Resource Practices in Developing Nations," Rural Sociology, Vol. 48, No. 1 (1983), pp. 44-59.

Similarly, agroforestry can be optionally adopted by individual farmers on their own land or collectively, particularly in village woodlots. Some forms of agroforestry involve a mixture of individual and collective adoption. For example, where shelterbelts are established to prevent desertification, projects must extend across numerous private holdings to be effective and must involve joint, cooperative action. The Majjia Valley Windbreak project in Niger involved this type of collective adoption (Brechin and West, 1982). In another mixed form, optionally adopted forestry projects on individual farmers' land is supplemented by collective shared labor exchange in planting and plantation protection. This mixed model has been implemented, for instance, in northern Fulbe villages in Upper Volta (Thomson, 1980a, p. 12), and in the Kordofan region of Sudan (Hammer, 1982, p. 52). In such mixed models the particular problems encountered in collective adoption must be confronted.

In making the decision of whether to seek optional or collective adoption of agroforestry projects, donor organizations and host country agencies must balance two major conflicting considerations. On the one hand, optional adoption is usually easier to achieve in the aggregate; on the other hand, it raises critical problems of equity and access by the poorest strata, especially the landless, to the benefits of agroforestry.

The general literature on diffusion of innovations in rural development suggests that collective adoption proceeds more slowly and is more difficult to achieve than optional adoption (Rogers and Shoemaker, 1971, p. 36; Gotsch, 1972, p. 334). Most analysts have found that optional adoption of agroforestry projects on individual farms is easier to achieve than collective adoption in village woodlots, etc. especially where there is a lack of collective action tradition (Thomson, 1980a, p. 12; Thomson, 1981a, p. 33; Noronha, 1980, p. 37; Winterbottom, 1980, p. 14). However, some analysts have found that other factors make more of a difference in project success rates than whether projects were optionally or collectively adopted. For instance, an agroforestry appraisal team in Upper Volta concluded that:

> the chief factor influencing the plantation success is not the kind of plantation (family or village), nor its location, nor its size, but the continuity and quality of encadrement -- the degree to which people were convinced that the plantation would yield significant benefits to them...and the extent to which they were assisted and encouraged, (CILLSS, 1979).

Reliance on optional adoption often leads to social inequity and lack of access to project benefits for the poorer strata. This has been extensively documented for optional adoption in general rural agricultural development, especially green revoltuion technologies that require intensive resource inputs (e.g., Gotsch, 1972; Röling et al., 1976; Saint and Coward, 1977; Griffin, 1971; Cohen, 1975). Similar inequities impacting the lower strata occur in the optional adoption of agroforestry by individual

farmers. Numerous analysts have documented that large farmers are able to individually adopt agroforestry innovations more than small independent farmers, and tenant farmers due to greater land availability, greater ability to take risks, and greater power and security in property rights control over project benefits (Noronha, 1981, pp. 3, 6, and 10; Cernea, 1981, p. 19-21; Hammer, 1982, p. 61; FAO, undated, p. 40). And the landless, which make up a large and often increasing proportion of the population in many rural areas, are totally excluded. It is the landless and poorer small farmers and tenants that are in greatest need of the benefits of agroforestry, especially fuelwood. As a recent FAO (undated, p. 15) report noted "the poorest members of the community are always among the first to suffer from shortages of gatherable fuelwood." At the same time, AID's development assistance policy in the renewable energy sector includes "a special commitment to meeting the small but truly critical needs of the poorest citizens, those living at or near the subsistence level" (McPherson, 1983, p. 26).

If the poorest of the poor are to benefit from agroforestry, then significant portions of development assistance support will need to be channeled into collective adoption of community forestry projects at the community, or subcommunity level (Noronha, 1980, p. 38; West, 1978). This situation is no different than for many other types of agricultural innovations. For instance, Gotsch (1972, p. 333), Goss (1979), and Rahim (1968) have found that the tubewell has to be collectively adopted if the poorest farmers are to have any access at all to this technology.

With this need in mind the following sections deal with five major sociological factors and barriers to collective adoption that must be dealt with more explicitly in agroforestry design and implementation. These factors are:

(1) the contrast among equity issues in optional and collective adoption;
(2) the special importance of property rights considerations in collectively adopted natural resource projects and their relation to equity;
(3) the problems that community factions present for collective adoption;
(4) the degree of prior community organization and the role of community organizing and social learning in collective adoption; and
(5) the role of indigenous leadership in collective adoption.

The first three factors can be grouped under the more general processes of structural factors in the distribution of project benefits. The last two are concerned more with internal organizational factors in the social organization of collective adoption. Central to this discussion is an analysis of the role of equity in collective adoption. Our basic thesis is that unless fundamental equity is assured community

members will not perceive benefits to their self-interest and hence will not sanction collective agroforestry projects or participate in their implementation. The issue of equity also permeates two closely related factors -- property rights and community factionalism. These structural factors strongly affect equity in the distribution of project benefits. In addition to these structural factors influencing equity, there are a number of organizational factors and dynamics that are critical to the achievement of collective adoption. Collective adoption implies not just decision but also collective action and organization to forge consensus and to engage in collective implementation and long-term project management. This requires attention to the structure and dynamics of community organization (and the potentials and strategies of community organizing) and the development of indigenous leadership in this organizing process for collective adoption.

ISSUES OF EQUITY

Distributive Equity and Collective Adoption

While avoiding many of the problems of differential optional adoption, a different set of equity problems arises in collective adoption. In particular, the danger exists that subgroups within the community may attempt to monopolozie benefits from collective projects. This differential distribution of collective benefits has two important consequences: (1) it can create resistence to collective adoption leading to project failure; and (2) it leads to problems of inequity and differential social impacts on the poorest strata.

Collective projects are likely to be resisted by those who benefit least from existing distributive mechanisms (Alexander, 1975). Often official rhetoric promises equitable distribution of collective project benefits, but, in fact, benefits are monopolized by power elites in the community (Baily, 1980, p. 22; Berreman, 1967, p. 102; Haney and Haney, 1976; United Nations, 1971; Uphoff and Esman, 1974, pp. 64-66).

The sensitive distribution issue can block adoption of collective projects at several stages of the adoption process. The Rogers and Shoemaker (1971) model seems to stress the critical importance of the decision stage. When projects are blocked at that stage, it is often because of a failure to reach agreement over labor contributions for implementation due to a perceived inequity in the distribution of benefits.

Oyugi (1963, p. 12) suggests the general rule that "popular participation depends upon the amount of direct benefit that the individual or family can hope to derive from the particular development project." This theme is echoed by other researchers (Almy and Mbithi, 1973, p. 624; United Nations, 1960, pp. 41-63).

The general relationship between expected benefits and participation in collective projects has been well documented in the specific case of community agroforestry. Villagers are concerned about both monopolization by power elites within the community and expropriation of project benefits by external forestry agencies that sponsor or assist with community forestry projects. As Noronha (1981, p. 10) concludes "villagers must be convinced that they, and not village 'big-men' or the government officials, will harvest the benefits of a community forest." There is an empirical tendency for both of these situations to occur. Horowitz and Badi (1981), and Cernea (1981) have documented the monopolization of community forestry project benefits by community elites. Thomson (1980a), Weber (1977) and Hoskins (1980) have documented expropriation of community woodlot benefits by government forestry services. In some cases this is clearly stated initially, and the proportion of benefits allocated to local needs is simply too low to motivate local participation. In other cases (e.g. Weber, 1977) local villagers were promised significant benefits by forestry officials, and then given only tree branches at the time of harvest. Village cynicism about expected benefits is thus often based on bitter experience, and not just on irrational fears.

Whether based in past reality or misperception, villagers in many areas are highly suspicious of collective forestry projects, because they perceive, rightly or wrongly, that they will not receive equitable benefits. In Upper Volta, for instance, Hoskins (1980, pp. 164-165) surveyed local villagers and found that "when asked who would benefit from trees that lived, residents gave various answers: the government, the Forestry Service, the village chief, for the foreign project designer; others were unsure or unwilling to hazard a guess. Few thought they would receive any wood after harvest." Conversely, where local people have been given a greater degree of local control (e.g., in some projects in Senegal), they have felt greater assurance that they would retain benefits which in turn contributed greatly to the success of the project (Hoskins, 1980, p. 167).

It may be easier to create structural change to assure local people benefits in relations to external forestry agencies than in the case of monopolization of locally retained benefits by powerful individuals or strata within the community. In the former situation, the first step should be to convince host country forestry agencies that village woodlots will fail unless they grant a significant proportion of the benefits to local people. They can be shown that they will reap greater aggregate benefits for nonlocal needs through increased plantation success rates by releasing a greater share of benefits for local needs in each woodlot project. Secondly, arrangements for the

allocation of the local share of benefits must be firmly established in written contracts (Romm, 1978, p. 3; Noronha, 1980, p. 7). This will help to (1) insure that forestry agencies fulfill their stated commitments, and (2) reassure villagers that they can expect to receive promised benefits. The granting of aid money should also be tied to these kinds of expectations and explicit assurances.

The prevention of monopolization by power elites within a community is a more difficult task. First, it is important to recognize two important qualitfications on the relationship between expected benefits and participation. Bolnick (1976, p. 144) has found that "though contributions are in part related to benefits, they are also related to the strength of direct and indirect social influences, the distribution of which may be totally unrelated to benefits." In research on collective adoption of small-scale irrigation projects in the Philippines, Kikuchi et al. (1978, pp. 220-25) have found that labor contributions in relation to benefits did not need to be absolutely equal across all groups to gain voluntary participation. But they did need to guarantee a net gain in benefits for each group.

In other situations, disparities in land ownership and power may be so great that attempts to achieve equitable community-wide collective adoption may be doomed to failure (Uphoff and Esman, 1974, pp. 64-66). One important strategy for countering this may be to work with subgroups within the community rather than with the community as a whole. If class structures are expected to prevent equitable distribution of benefits from community-wide projects, one can sometimes work with subunits of relatively homogeneous social strata. This was successfully done, for instance, in the Camilla project (West and Light, 1978, p. 357).

This strategy, however, may be resisted by vested interests. In the Chilalo Agricultural Development Unit in Ethiopia, efforts to stimulate cooperative reforestation and other collective adoption projects among small farmers was greatly impeded because of resistance from large farmers (Coombs and Ahmed, 1974, p. 98). Large-scale interests may resist innovations in lower strata for a variety of reasons. They may be seeking: (1) to monopolize external project aid for themselves; (2) to block and control potential competition for markets; (3) to monopolize access to key natural resources; and/or (4) to maintain the status stratification system (i.e., wealthier high status groups often seek to block advancement of low status groups as this threatens their dominant status position). In dealing with this vested interest resistence to social change, Berreman (1967, p. 406) emphasizes the importance of aid strategies that will benefit both upper and lower strata, thus buying off the one group to permit assistance to the other. This strategy is being used in numerous World Bank aid programs (West and Light, 1978, p. 350).

Land Tenure, Property Rights and Distribution of Benefits

The issue of distribution of community forestry project benefits is frequently embedded in the structure of property rights systems. Collective projects on communal land can fail if they do not take account of distributive mechanisms in traditional collective property institutions, especially where adaptive property norms exist for the collective management of commons resources (e.g., Mitchell, 1976; Orlove, 1976; Reiger, 1977, p. 3). For example, in a project involving range management practices in Somalia (Mahoney, 1966), technical grazing experts sought to gain improved range management through demonstration areas where new well drilling would be concentrated, range herds reduced, and private property rights introduced. Prevailing customs with respect to property rights prevented collective agreement that would allow certain grazers exclusive rights. Friction that developed caused the cancellation of the project. Similar dynamics involving pastoral grazing rights occurred in the Sahel (West and Light, 1978, p. 355).

Numerous problems related to property right norms and practices also complicate collective agroforestry projects on commons lands. In many parts of Africa "no provisions exist for tribal or communal lands to be dedicated to long-term use of the kind required by forestry" (FAO, undated, p. 40). No property right norms exist for handling this new type of long-term land use. This is particularly the case in areas of Africa such as northern Kenya where land tenure is communal but where land use is primarily devoted to nomadic pastoralism (Burley, 1980, p. 455).

Even in primarily agricultural zones, commons areas that have been traditionally used for grazing can spark heated land use conflicts when community forestry land use is introduced, and grazers often resist or even sabotage community forestry efforts (Whyte and Williams, 1968, p. 54). Romm (1978, p. 30) has suggested that where these conflicts occur, that projects either be moved, or supplemented with intensified fodder production on other nearby lands.

Another concern in some areas is the stability of collective land tenure of common lands. In India, village commons lands are subject to redistribution and thus villagers cannot be assured that land designated for forestry today will not be "given away" to other individuals at a later date (Noronha, 1981, p. 8). However, a more serious and widespread problem is not an official governmental expropriation of commons land, but rather the informal and often unnoticed appropriation of formally commons land by powerful local individuals. What is formally commons land becomes in reality private property controlled by a few individuals. Cernea (1981) has conducted the most detailed study of this process on the "Shamlat" (village commons)

land in Pakistan, but this same process has been observed in the White Nile province of Sudan (Horowitz and Badi 1981, p. 19), the Keita region of Niger (Steve Brechin, personal communication), in Himachal Pradesh, India, and in Kenya (Noronha, 1980, p.18). Past failure to recognize this difference between formal commons land and individual property rights control can cause project failure and inequitable distribution of benefits. It is important, therefore, that actual land tenure structures be carefully investigated in preproject assessments.

The products of any collectively adopted project become collective property. Participants' belief that these collective products will be protected is important for initial project adoption. And actual successful protection of that collective property becomes a key to long-range success of the project. This has been a problem for a variety of collectice resource projects including cooperative farming (Lele, 1975, p. 74), collective irrigation (Coward, 1973, p. 240), community fuel woodlot projects (Eckholm, 1976, p. 103; Thomson, 1977, p. 63), and collective grazing (Horowitz, 1977, p. 3). In such cases, coercion is inevitably involved in voluntary collective adoption (Hardin, 1968). Not only must there be an agreed upon coercive apparatus, but this apparatus must be perceived by all participants in the collective project as a credible, effective deterrent. Reiger (1977, p. 8) has emphasized the critical importance of this perception in programs to end collective forest destruction in the middle hill lands of the Himalayas.

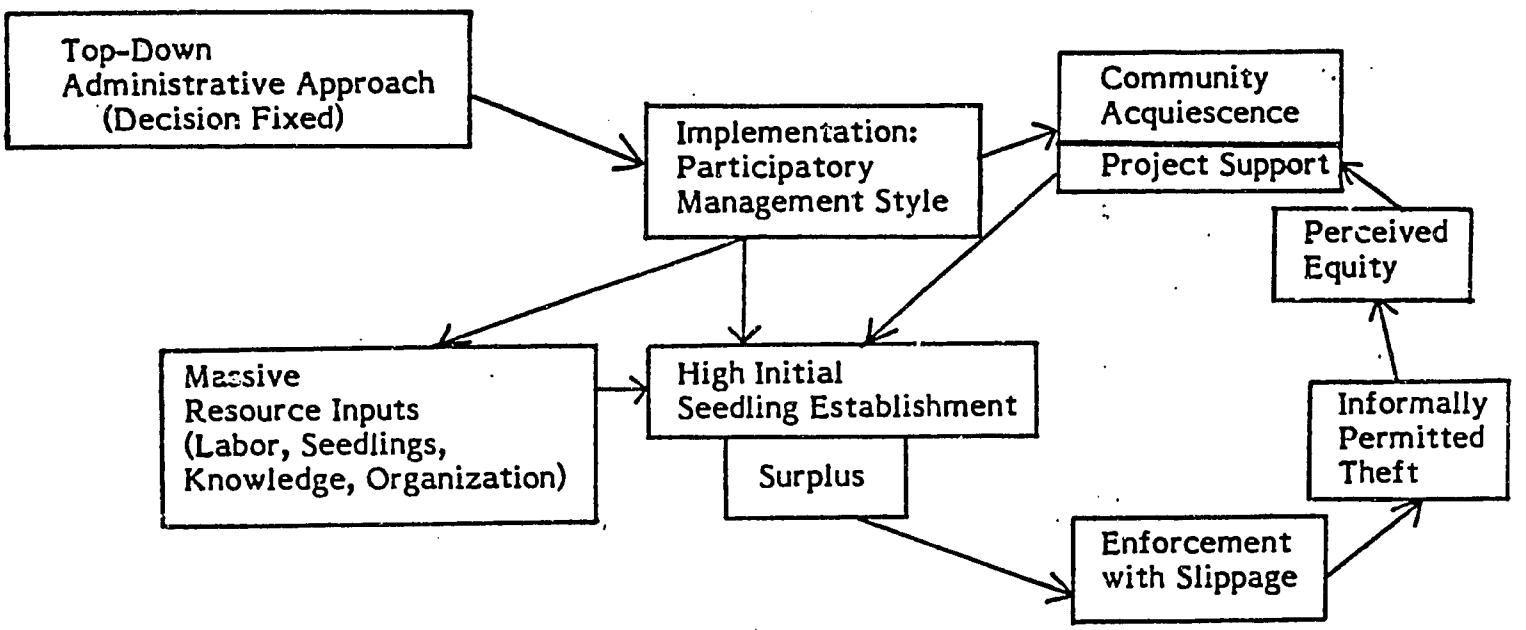
Brechin and West (1982, pp. 91-92), however, have found an exception to this relationship between theft control and collective adoption success for community forestry projects in Niger, West Africa. Where equitable distribution of benefits is blocked, as it was in the Niger projects, limited theft may have the latent function of increasing equity and hence increasing tacit support for project adoption (See Figure 1).

Rights in Trees

The difficult institutional situation in Niger discussed above is complicated by their system of property rights in trees. "Protected species" are certain highly valued species protected by the forestry code through a permit system (Thomson, 1981b). "The Nigerian Forestry Code also states that an individual who plants a tree owns it. If a villager plants a protected species, however, the forestry official may lay claim to that tree" (Brechin and West, 1982, p. 86; see also Thomson, 1980a, 1981b). These tree tenure rules severely restrict villagers' incentives to engage in reforestation except on their own compounds where they can more firmly establish ownership. Conversely, unprotected species may be planted but because they are unprotected they are treated

FIGURE 1

THE LATENT FUNCTION OF THEFT MODEL



SOURCE: Brechin and West (1982, p. 96).

as a free good in the local community. Thomson (1980d, p. 50) has documented cases where unprotected species planted by a farmer were freely taken by neighbors. Thomson (1981) argues that the disincentives due to the protected and unprotected species forestry code will not improve until the forestry code in Niger can be changed. But this may be a long time in coming. Thus a number of intermediate strategies are needed to minimize the effect of these tree tenure rules until they can be changed. For instance, the CARE forestry program in Niger is experimenting with a new type of village woodlot program in which CARE gives protected species to local village farmers, who in turn plant them in CARE sponsored woodlots. CARE keeps careful records of which farmer planted (and hence owns) which trees. This gives assurances that the Forestry Service will not claim them later. Another strategy would be to encourage the collective adoption of unprotected species. While these would not be formally protected by the government, local norms and agreements among villagers in collective projects could perhaps be accompanied by systems of mutual protection activities to enforce such local norms against violators.

Security of Land Tenure and Access to Benefits

Another factor of great importance is the security of land tenure. Research conducted on U.S. farmers in the 1930's found that tenants with insecure tenure were much less likely to adopt soil conservation practices than owner-operators. Similarly, those without security of land tenure are hesitant to adopt agroforestry practices especially given the long time frames involved in forestry activities (Thomson, 1981a, p. 3; Simmons, 1980, p. 39; FAO, undated, p. 40; Hammer, 1982,p. 61). Not only are they likely not to adopt agroforestry practices themselves, but they also have been known to sabotage agroforestry plantings initiated by landlords. For instance, rural reforestation programs have failed in Ethiopia due to the quasi-feudal land system. Because the land to be planted belonged to the landlord, the peasants felt that all benefits would flow to the landlord. Thus, peasants hired to do the planting sabotaged the project by planting many of the seedlings upside down (Eckholm, 1976, p. 109).

One long-range solution is to encourage land reform to give peasants free-holder title to the land they cultivate. The World Bank has experimented with pilot programs involving getting tough on land redistribution by tying aid money to effective land reform with some success. However, these strategies are likely to be strongly resisted by the structure of rural domination in host countries, involving not just landlords but also their political influence and control over government institutions as Grindle (1977), for instance, has documented in Mexico.

A more intermediate, pragmatic strategy may be to seek leverage for creating a greater security of tenure, which stops short of full property rights redistribution

(Simmons, 1980, p. 39). There are no easy solutions to these issues in rigidly stratified societies. But in areas where farmers are not independent free-holders, these problems must be squarely faced and points of leverage found and applied if agroforestry is to have any chance of success under these types of social structures.

Another variant of this problem occurs in the agri-silviculture system, the "Taungya" system, in which the government Forest Service becomes the landlord on government forest lands that were frequently nationalized from formerly commons lands that had been used for shifting agriculture. While peasants incorporated into forest villages sometimes receive benefits they might not have otherwise have had, their poverty remains stark and their share of the yield from the system remains meager; they continue to exist in stark poverty, while frequently large revenues and profits are generated from the sale of teak and other forest crops (Olawoye, 1975; Van Nao, 1978; Chapman, 1979; King, 1968). This has created a sense of bitterness and resentment among many of the peasants involved. Their bitterness in many areas is heightened by the fact of the history of government nationalization of forest lands (e.g. Tucker, 1982b; Berreman, 1972). This is a social impact that must be addressed in its own right, but it is also a barrier to the adoption and expansion of the system, which on technical grounds can be highly efficient and successful. As Van Nao (1978, p. 13) observes, "any continuation of the sense of frustration of the cultivator is a major obstacle to the development and expansion of agri-silviculture." Numerous analysts have argued that a greater proportion of the benefits of the forestry proceeds, or other compensation should be granted to the cultivator (Van Nao, 1978,p. 14; King, 1968; Ball, 1977). Chapman (1979, p. 59) has suggested that the basic system of land tenure with government ownership should be reconsidered. This approach has been tried successfully in the settlement of unemployed and landless persons in India. Here the Forest Service paid them to plant trees. "Every year the project gave each person who maintained his trees more land to plant. When the trees were grown, the participants received a percentage of the harvest and retained the land" (Hoskins, 1980, p. 177).

Factions and Power

The prevalence of factions within peasant communities often complicates the problem of achieving effective adoption of collective practices (Niehoff, 1966, p. 225). Comparative evaluations of the success of cooperative associations in the Camilla project, for instance, revealed that those which were relatively free of factional divisions had a much greater chance of success (Hussain, 1967; Pakistan Academy for Rural Development, 1964, p. 38; Rahim, 1968). Factions are more problematic in the case of collective adoption than they are in optional adoption (Constantine, 1970).

Similarly, factions can be a major barrier to the collective adoption of agroforestry projects such as village woodlots (Thomson, 1977; Noronha, 1981, p. 8; Noronha, 1980, p. 12; Coombs and Ahmed, 1974, p. 98). In agroforestry programs in India, Noronha (1981, p. 8) goes so far as to assert that "the existence of powerful factions preventing common action was the most important reason for the failure to initiate woodlots." Coombs and Ahmed (1974, p. 98) have observed primarily class-based factions preventing collective reforestation in Ethiopia, whereas in India, Noronha (1980, p. 12) observed that factional divisions fall more along lines of ethnic status group cleavages.

Although collective adoption under conditions of community factionalism is difficult to achieve, Whyte and Albert (1976) suggest from their research in Latin America that absence of conflict may simply indicate a lethargic resignation, which also makes collective action difficult. Factional conflict may indicate a vitality that can be harnessed in constructive directions to achieve collective adoption. Schwartz (1968) has found that where factions are involved in crosscutting lines of conflict[2] and no faction is strong enough to dominate the decision process, coalitions for cooperative action could be formed. When these conditions are not present, it may be necessary to work again at the subcommunity level to achieve collective adoption within homogenous factions. The external conflict may actually increase in-group solidarity and communication and facilitate within-group adoption (Constantine, 1970).

In some areas, factions have formed precisely along economic lines that divide collective aspects of the economy, based in cooperatives, from noncollective sectors (Bertocci 1970; Carras, 1972). Here, factional conflict strengthened the solidarity of the co-ops and added incentives for collectively adopting new practices as a means of economic and political advantage in the factional struggle.

In lineage-based factions on American Indian reservations, Fowler (1973) has found that hiring a neutral project manager not aligned with any given faction can be one way to achieve collective adoption across factional lines. In sum, while the existence of factions presents greater problems for collective adoption than for optional adoption, the existence of factional divisions does not necessarily preclude successful collective project adoption. However, here also, collective adoption has implications for change in the balance of power economic resources, and prestige among factions, which can lead to resistance to adoption of the planned social change.

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[2]"Crosscutting conflict" is defined here as conflict groups who are in conflict on some issues but who are in coalition on other issues.

ISSUES OF ORGANIZATION

Community Organization

Numerous observers have emphazied the importance of effective local community organization for the implementation of agroforestry projects (Thomson, 1980a, p. 12; Noronha, 1981, p. 6; Cernea, 1981, p. 28; Romm, 1978, p. 24; FAO, 1980, pp. 3, 44, 81-82; Winterbottom, 1980, p. 11; Brechin and West, 1982, pp. 88-89).

There is an important debate in the general literature on rural development over the appropriate role of community organizing. Stavis (1976) argues that lack of local organization is one of the key barriers to effective rural development. This theme is echoed by Owens and Shaw (1974) and Rice (1971). Erasmus (1961), on the other hand, argues that community organizing is not worth the trouble and effort to gain collective group action when such action is not essential for project success. Where collective organizing has been achieved, however, it has been beneficial (Uphoff and Esman, 1974).

In the midst of this debate, the specific differences between optional and collective adoption need to be recognized. Community organizing may be important for optional adoption. However, collectively adopted innovations, such as community fuel woodlots, virtually necessitate investment in at least some degree of community organizing (Coward, 1977a, 1977b).

Community organizing for collective adoption is especially critical, but at the same time more difficult to achieve, in communities without strong collective traditions (Banfield, 1958; Hornik, 1977). However, we must avoid the automatic assumption of unmotivated, unorganized amoral familism in peasant cultures (Whyte and Albert, 1976).

Tribal systems with traditional collective economic organization present the "ideal type" of societies based in collectivist traditions (e.g., Lang, 1971; Mitchell, 1976). However, just as we must avoid overstereotyping conditions of amoral familism, so must we avoid overstereotyping images of collectivist traditions. As Bailey (1980, p. 20) observes of rural Malay society:

> Government officials and students of rural Malay society alike often hold the rather romantic notion that rural Malay communities possess an inherent cohesiveness that enables and encourages members of these communities to work together for the common good. Many government programs based on this misconception seek to mobilize supposedly preexisting local energies and resources for development projects.

Long and Winder (1975, p. 85) make a similar point about reliance on systems of traditional labor exchange in Peru that no longer exist. Thomson (1981, p. 32) has

made the same observation about reliance on assumed traditions of collective action for collective agroforestry projects, where such traditions, in reality have become "too eroded" to support such activity.

Thomson (1980c, p. 14) observes that successful collective agroforestry projects have tended to occur where preexisting organizational traditions and capabilities already exist. He goes on to assert, however, that to invest in community organizing where there are weak organizational capabilities may not be worth the costs. This may perhaps be true if the costs of organizing are incurred just for one single forestry project. However, if it is done as a long-range investment for a series of forestry projects or as part of an integrated rural development project (see below) involving benefits to numerous development efforts including agroforestry, it may be more cost-effective.

The use of community organizing within an integrated rural development program which includes agroforestry has the additional benefit of sequencing organizing efforts to maximize the effectiveness of basic community organizing principles and strategies. It is important to stress the difficulty of organizing directly for the adoption of collective projects, especially where benefits to the individual may not be immediate as occurs in agroforestry. It is, of course, one of the cardinal principles of community organizing to focus initially on projects of immediate interest that can be easily achieved. Then these new or strengthened social organizing capabilities that have been developed within the community can be utilized in the achievement of more complex, long-range projects. This strategy has been effectviely used in community reforestation programs in Korea (Kincaid and Yum, 1976, pp. 83-90), in Africa (Hoskins, 1980, pp. 166-167), and Honduras (FAO, 1980, p. 53).

Coward (1973) and Dunn (1971) emphasize that where possible the development of such organizing capabilities should be internally generated rather than externally imposed. They contrast a "social learning" model with the traditional diffusion of innovations paradigm. Coward (1973, p. 240) defines social learning as internal, experimental innovation by a group in which "the users are also the designers" of the innovation. Social learning is primarily relevant to "sociocultural innovations," and it may therefore be particularly important in developing the collective organization capabilities necessary for collective adoption. Coward (1973) cites several cases involving social learning in the development of project management systems for irrigation in the Philippines and group farming in Japan.

The scope and forms that community organizing assumes for agroforestry are also important considerations. If traditional organizational forms in the community are to be utilized, it is critical that they be carefully and adequately integrated into

the project design. As Noronha (1980, p. 42) cautions, "it is difficult to expect traditional organizations to implement project components (such as village woodlots) where there is no explicit recognition of their role, and no formal provision for their participation in decision making and implementation." Where such formal linkages can be established Naronha feels that traditional organizations should be drawn on as far as possible. However, an FAO study group in Jamaica (FAO, 1980, p. 73) observed that "although there is a Jamaican Farmer's Association, this is not the ideal organization, since what is needed is one tending toward the productive conservation aspect."

Another related issue is the scope of organizing efforts. Should one try to organize an entire village, or just subsets, through voluntary membership, for instance, in forest cooperatives? Cernea (1981, p. 31) suggests that the latter course of action might prove to be a "more coherent and better defined organizational structure," and notes that this organizational scope and form has been effectively used in cooperative agroforestry efforts in Pakistan. Blair et al. (1983, p. 33) also favor this approach to working with subunits in the community because of the greater potential for social homogeneity and maximum social influence within a smaller group.

However it is done, it is important to recognize that community organizing for collective adoption also may affect changes in power relations that can threaten vested interests and thus lead to further resistance to social change (e.g., Coombs and Ahmed, 1974, p. 98). Because community organizing is inevitably involved in collective adoption, such projects are a double threat to vested interests, for they alter both the access to resources and the structure of organizational bases of power in the community. Thus there is a tendency for upper class interests either to resist such efforts or to co-opt them to reinforce patterns of rural stratification (Gotsch, 1972, p. 338).

Indigenous Leadership and Collective Adoption

The development of indigenous leadership is also more important in collective adoption than in optional adoption. In optional adoption the main function of leadership is frequently a more passive role of "opinion leadership." In collective adoption, however, leadership must not only mold opinion but must actively engage in community-organizing efforts to seek enough consensus for joint decision by mobilizing labor contributions, and by developing and managing organizational systems for implementation and long-term project management. In sum, collective adoption depends much more on actual active leadership functions and activities that need to be sustained over the life of the project. Thus Coward (1977b) has identified the problem of identifying, developing, and maintaining adequate leadership as one of the most

critical problems in collective adoption. Noronha (1980, p. 31) and Thomson (1980c, p. 19) have recognized the importance of indigenous leadership in the collective adoption of agroforestry.

Collective adoption involves at least a three-stage process of initiation, legitimation, and implementation. Studies by Kerr (1970) and Rahim (1968) suggest the importance of identifying different leaders in the different stages of the collective adoption process. Kerr (1970, p. 104) has found that introducers tended to be younger, better educated, with more extrasystem contact than other leaders. Legitimators were the oldest leaders. They had the highest social status but were not necessarily the wealthiest leaders. Implementers tended to fall between the other two types in age and were more locally oriented. While these leadership functions are important to distinguish, they may not always be represented in different individuals. In the case of the Korean reforestation program cited above (Kincaid and Yum, 1976), one leader played all these roles.

Noronha (1980, p. 31) reminds us of the importance of distinguishing formal leaders, from informal leaders who may have real power to facilitate or block active community participation in agroforestry projects. This may be an especially important distinction in countries like Niger where traditional community leadership has been consciously undermined by centralizing national political forces (Brechin and West, 1982, p. 86). Also, leadership patterns experienced in other community development sectors may not translate into agroforestry. As Thomson (1980c, p. 19) observes, "if reforestation is a new activity, leadership authority may not be easily transferable from one or more traditional activities to the new enterprise."

The background and orientation of leaders is related to the success of collective adoption. Rahim (1968) has found that cooperative associations in Camilla whose leaders were more highly educated and oriented towards modernity had the highest rate of collective adoption success. The social origin of leaders within the local social stucture can affect the participation of different strata and the perception of equity as we noted above in the case of factions. It can also help to explain the relationship between social influence and labor participation found by Bolnick (1976, p. 144). For instance, Kikuchi et al. (1978, p. 220) have found that the labor share of tenants on a collectively adopted irrigation project was the highest among the various strata involved, although their share of benefits was not the greatest. They have found that this occurred primarily because most of the leadership for the project came from the share tenant strata. There may have been both a greater degree of social influence within that group and a greater assurance of delivery of their share of project benefits.

Coward (1977b) has found that one of the key functions of effective leadership is an ability to mobilize participation, and this ability, in turn, depends heavily on reciprocal solidarity bonds connecting members of the group. The strength of these bonds depends in part on the size of the group, which he has found should not exceed seventy to eighty members. This may put a limit on the size of the social unit for which collective agroforestry projects should be designed.

In considering highly concentrated systems of power, we must be cautious about confusing coerced labor with the social influence exerted by leaders in collective adoption. Erasmus (1961, p. 94) recounts the case of a project in which it appeared that a local priest was playing a constructive leadership role in mobilizing local villagers in a voluntary, cooperative self-help project. Later it was discovered that, to further his own career interests, the priest had forced peasants to participate on pain of loss of burial, baptismal, and marriage services.

Reorientation of Extension Functions

The implications of the central need for community organizing and development of indigenous leadership implies a needed shift in extension service functions away from a singular focus on information dissemination and toward facilitation of community organizing and indigenous problem solving. This would be especially important for collective adoption projects in agroforestry, but would also help to facilitate the optional adoption of agroforestry practices by individual farm families. This approach is strongly supported in the general literature on rural development (Holdin, 1972; Coombs and Ahmed, 1974; Jimenez-Sanchez and Laird, 1974; Owens and Shaw, 1974; and Uphoff and Esman, 1974).

INCENTIVES

The long time-frame involved in establishing sustained yield agroforestry projects reduces the relative perceived economic advantage of these innovations to peasants on the margins of existence. Even if plantations are started, they may be ripped out by residents desperate for fuel in the immediate present (Westoby, 1975). Studies of long-term innovations suggest that (1) a long-term benefit is more likely to be accepted if it is linked with short-term benefits, and (2) a long-term benefit is more readily accepted if the adopters are materially aided or subsidized in the interim (Erasmus, 1952).

Numerous analysts have emphasized the importance of incentives in stimulating local interest and participation in agroforestry efforts, especially given the long time-frame involved (FAO, undated, p. 34; FAO, 1980). However, before special

supplementary incentives are considered it is important to recognize that adequate access to major project benefits is the "best and most important incentive" (Noronha, 1980, p. 43; see also Romm, 1978, p. 21 and FAO, 1980, p. 61). It appears that where institutional structures prevent this from occurring, as in Niger, reforms in the institutional structure may provide the most needed form of "incentive" (Thomson, 1981, p. 36).

However, even with adequate distribution of benefits, other supplementary incentives may be needed. Such incentives include paid labor in planting, food for work programs, supplemental fuelwood, access to fair credit, payments to farmers during periods of seedling growth until project benefits are realized, and other forms of incentives (FAO, 1980; FAO, undated). There is an important debate over how much agroforestry programs should rely on such supplementary incentives. On the one hand they may be needed to encourage participation; on the other hand, they may foster dependence and drain project financial resources.

An FAO study team found in Jamaica that success rates in aforestation increased significantly only when levels of incentives were increased to the point where 40 percent of establishment costs and two years of maintenance assistance was provided. The study team (FAO, 1980, p. 48) cautions that:

> None of the parties involved must take them to be a gift: they must be a stimulus to the peasant's incentive and sense of responsibility. Continuous aid which does not produce self-development, and the application of kinds of incentives in which the peasant has only a passive role lead to paternalism and to his growing dependence on the state.

Yet, it may not be so easy to tinker with the forms of incentives to avoid this, and admonishing the poor not to become dependent may strike them as a cruel joke. Other analysts see far greater dilemmas in the provision of incentives. Thomson (1980a, p. 18) observes that:

> Forest service agents are often tempted to use physical and monetary inducements to promote at least the beginnings of woodstock management. In doing so, they risk creating expectation on the part of peasants that such inputs should be provided in the future, and thus encouraging villagers to bargain over the amount and character of inputs and inducements, as conditions for participation...

Cernea (1981, p. 26) echoes this concern. He argues that full subsidy in particular, "would be likely to reinforce paternalistic expectations and apathetic attitudes among farmers toward replanting trees, and may undermine attempts to generate more responsible participation." He also argues (p. 5) that in using full subsidies prohibitive because it concentrates resources and restricts the number

of projects that can be initiated. However, he does acknowledge that some degree of incentive should be provided so that small farmers can participate (p. 26).

This is an important debate, and adequate scientific results are not yet in to fully judge how this dilemma can best be balanced, or specifically what levels and what kinds of incentives maximize the positive effects of incentives while minimizing negative side effects. Further study in controlled comparative pilot projects is badly needed to sort out these issues.

However, if incentives are to be given, a number of principles are emerging with respect to the forms and ways in which they should be delivered. First, it is fundamentally important that whatever level and form of incentives are promised are delivered in full and on schedule. Hoskins (1980, p. 164) documents projects in Upper Volta where promised incentives and subsidies were not delivered which led to widespread discouragement and cynicism in local communities.

Second, incentives must be designed in ways that fit into local cultural patterns. For instance, sometimes food for work incentives include lunch. However, in many areas it is just a cultural expectation that contributed labor comes with lunch from long-standing traditional norms of labor exchange (FAO, 1980). Similarly Noronha (1980, p. 6) observes that "incentives (such as education or health services) to which participants believe they are entitled as of right may not suffice to induce local participation."

Third, one must be very cautious that incentives are structured in ways that indeed provide an incentive to wait for long-term benefits. For example, reforestation programs in hill land regions in the Philippines used direct wage labor incentives to gain local participation. Officials soon discovered, however, that the local workers were sabotaging the young plantations through intentional burning and other means, in an attempt to maintain the flow of direct economic incentives from the reforestation program (West and Light, 1978, p. 369).

Noronha (1980, p. 43) also warns of these dangers of paid labor incentives. This suggests that incentives should be structured to reward successful survival rates rather than simply number of trees planted. However, this creates another dilemma because a delayed incentive may not be a real inducement. As Noronha (1980, p. 6) suggests, "incentives should be designed so as not to delay rewards beyond the waiting capacity of the project population." A related dilemma occurs with respect to the payment of villagers to plant trees. On the one hand they may not participate in tree planting if they are not paid. However, Hoskins (1980, p. 177) points out that "participants paid to plant trees may assume that the project manager or government owns the tree and will fail to maintain it." Hoskins (1980, p. 177) observes that in Senegal these dilemmas

were resolved by paying a small amount each year for every tree that survived through that year. This created a survival rate of almost 100%. In another similar project where people were paid only to plant trees, the survival rate was only 20%.

Fourth, money paid to reimburse specific costs of planting and maintenance must be specifically tied to the performance of those specific tasks. If this is not done, monies supplied to cover costs are likely to be diverted and used for other purposes as occurred for instance in reforestation programs in Honduras (FAO, 1980, p. 54).

Finally, incentives must be designed in such a way that all members of the community can take advantage of them. As Blair et al, (1983, p. 16) cautions, "It is frequently noticed that despite all efforts and plans to the contrary, community members...already well-endowed are much better able to take advantage of measures and programs...including forestry incentives" (See also Brechin and West, 1982, p. 88). This cautions project designers to understand the full range of barriers that inhibit participation by the poorest farmers and villagers. Incentives should be designed to address the full range of barriers in order to encourage participation by the poorer strata.

ROLE OF WOMEN

It is now widely recognized that without the support and involvement of women, agroforestry efforts have a much less chance of success (e.g., Hoskins, 1979; Simmons, 1980; Ki-Zerbo, 1981). Women bear the brunt of the fuelwood gathering which in some areas such as Nepal can range up to 60 days per year of labor (Cernea, 1981, p. 30). Thus, particularly where wood is scarce, women have a greater felt need and self-interest in the success especially of fuelwood agroforestry (Hammer, 1982, p. 45). Women in many areas are often assigned the role in traditional cultures of tending and weeding crops including trees (Ki-Zerbo, 1981, p. 10). Hoskins (1980, p. 159) observed the consequences of the failure to involve women under these cultural conditions in West Africa.

> Several West African woodlot projects have failed even after they were planted with local village men who willingly planted the trees. They failed because they were located in regions where women traditionally do all the crop maintenance tasks. Since women were not involved in the project the trees died from lack of care.

In projects where women have been carefully involved for instance, in Senegal, project success rates have increased (Hoskins, 1980, p. 167). While the importance of involving women in participatory agroforestry is clearly documented, and now well

accepted in AID and other donor agency programs (Simmons, 1980, p. 39), the implementation of programs to actively involve women in many areas is a difficult task, not only due to resistance by traditionally male-dominated forestry agencies, but also because many traditional local communities are not used to giving major community involvement roles to women. In the Kordofan region of Sudan, for instance, local communities that engaged in community organizing through a system of elected representation included women only reluctantly, and only under strong pressure from outside donor agency representatives (Hammer, 1982, p. 43). In such situations external influence and pressure may be needed, but must be pursued cautiously so as not to alienate the community. Resistance by forestry extension services can best be overcome by hiring women extension agents (Noronha, 1980, p. 45). This was effectively done, for instance, in Labgar, Senegal (Hoskins, 1980, p. 166). This has the additional advantage of making it easier to involve women who may feel more comfortable dealing with women extension agents. This is especially true in cultures, such as the Islamic Hausa people in Niger, where public social interaction between men and married women is strongly frowned upon.

BUREAUCRATIC STRUCTURE AND CHANGE

At various points it has been observed that institutional and bureaucratic structures have frequently been major sociological barriers to the implementation of effective agroforestry programs. Indeed it is frequently not the peasants who need reforming, but the bureaucratic delivery systems. In this section the various issues in what Uphoff has called "bureaucratic reorientation" both within particular agencies to create a more participatory approach, and in the relations among them in building the needed linkages for integrated rural development programs will be discussed.

Bureaucratic Reorientation

Blair et al., (1983, p. 1) makes the fundamental observation that "rural institutions have crucial roles to play in furthering the involvement of local populations in forestry enterprises and in insuring local benefits are realized." In many areas, however, this requires a major restructuring of both institutional structures such as forestry codes (Thomson, 1980a) and host country bureaucratic agencies (Blair et al., 1983; Korton and Uphoff, 1981; FAO, 1980, p. 56; Winterbottom, 1980, p. 23; and Simmons, 1980, p. 94).

This requires specific strategies that Korton and Uphoff (1981) have termed "bureaucratic reorientation." Bureaucratic reorientation, in part, involves changes in individual bureaucratic attitudes and behaviors through education and training of both

current and prospective agroforestry specialists. However, an educational approach is insufficient in itself to create the needed changes. As Korton and Uphoff (1981, p. 5) note "here we should be careful not to 'blame the victim'. In part, and sometimes in large part, the observed behavior and manifest attitudes of government staff grow out of the bureaucratic context in which they find themselves." Thus, there is a need for structural changes in the pattern of expectations, incentives, and rewards within bureaucratic organizations to facilitate changes in the organizational context before individual behavior can be expected to change. The most important aspect of bureaucratic reorientation involves "changes in job definitions, performance criteria, career incentives, bureaucratic procedures, organizational responsibilities and the like" (Korton and Uphoff, 1981, p. 6).

Thus, just as in the case of incentives for peasants, material and career advancement incentives for foresters should be tied, not to successful plantings, but to successful survival rates to maturity, tied with education and requirements for participatory ways of achieving this along with monitoring of performance against these criteria. Once the context for the pursuit of their self-interest is changed, and their self-interest thus becomes tied to participatory approaches and successful implementation, their attitudes and behavior will be more likely to change than they would through educational means alone.

Yet it remains a thorny problem to convince well entrenched host country forestry agencies to submit to such a transformation. Donor agencies who wish to see their dollars spent effectively must devote a portion of their money and effort to educating and convincing political and bureaucratic leaders of the need for such a change in orientation. Such persuasion efforts can be enhanced by "tying strings" of requirements for bureaucratic reorientation activities to donor aid programs. How ever it is achieved, bureaucratic reorientation "will not occur without strong, consistent and 'committed' leadership from top bureaucratic and political echelon" (Korton and Uphoff, 1981, p. 6).

Although top officials must be convinced first (in a very top-down approach), the implementation of bureaucratic reorientation programs for participatory agroforestry must involve an open participatory approach (Blair et al., 1983, p. 52; Korton and Uphoff, 1981, p. 6). Experimental efforts in bureaucratic reorientation are currently being conducted in agroforestry programs administered by the Bureau of Forest Development in the Philippines (Korton and Uphoff, 1981, p. 6). The approach they are taking involves participatory educational efforts in the earlier phases. Once the need for change is recognized and accepted within the agency, then steps are taken to institutionalize those changes in the structure of incentives and reward systems. While

it is too early to fully evaluate the success of these field efforts, initial results are promising.

Integrated Rural Development Institutions

Bureaucratic reorientation is needed not only within particular bureaucracies, but also in relations between them. As Blair et al., (1983, pp. 36-37) assert, "meaningful progress in the forestry sector is in many areas dependent upon an integrated approach to rural development." Similarly, Hoskins (1980, pp. 160-161) views the lack of integrated planning and interagency coordination as major structural barriers to the effective implementation of agroforestry programs. As already noted the sequencing of community organizing activities can be more easily done within an integrated rural development approach and can be more cost-effective. Also, success in early phases around easier subprojects with immediate felt needs builds confidence and trust in the sponsoring agencies. As an FAO evaluation team (FAO, 1980, p. 53) notes, "an additional bonus is that social motivation, soil conservation activities, and agricultural extension build peasant trust in the project...thus promoting easier acceptance of the concept of reforestation, which is for them an innovation."

A number of analysts have stressed the need for an integrated approach because other felt needs are more urgent, and agroforestry is seen as irrelevant if these other needs are not met. They will be more willing to consider agroforestry aspects along with a package of other rural development efforts (Hoskins,1980, pp. 166-167; Hammer, 1982, pp. 62-63). Noronha (1980, p. 34) has emphasized the additional benefits that agriculture, livestock grazing, and forestry aspects can be better coordinated within an integrated program approach.

It is relatively easy to document the need for an integrated approach; it is much harder to implement it. In many areas such as northern India, long histories of interagency rivalries complicate this task (Tucker, 1982b, p. 23). It may be that the approaches to bureaucratic reorientation discussed above can be adapted by working simultaneously within each bureaucratic agency toward the goal of external reorientation, and bridging functions that would provide the needed foundation for effective integrated program development. This will also require greater coordination within subunits of donor agencies such as AID.

CONCLUSION

A number of key sociological factors discussed here seem critical to the implementation of a participatory approach to both the optional and collective adoption and long-term management of agroforestry programs. Again, it should be

emphasized that no single factor discussed is the key to success by itself; rather, it is the combination and interaction of the various sociological factors in an integrative approach that is needed. Further research and evaluation studies are clearly needed on these and other sociological dimensions, but hopefully enough is known of the major outlines of needed action to enhance the effectiveness of AID and other donor agency programs in agroforestry. It is hoped that this attempt at synthesis of our understanding of sociological aspects of agroforestry programs will help to achieve these ends. At times strategies proposed here of needed change are those that are difficult to achieve, some of which may even be viewed as controversial. While it is important to be pragmatic, one should remember that pragmatism must mean more than simply sticking one's head in the sand while the land and the people slip away.

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MICROECONOMICS OF AGROFORESTRY

by

William Magrath

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MICROECONOMICS OF AGROFORESTRY

by

William Magrath

INTRODUCTION

Economic analysis of agroforestry projects revolves around the selection and comparison of appropriate values for inputs and outputs. These projects often present special valuation problems such as the various unpriced and underpriced values that are typically involved in agroforestry (home consumption, environmental externalities, market failures). An additional set of economic issues relate to the analysis of a range of important institutional questions. Included here are the resource allocation implications of traditional structures of land and tree tenure and the difficulty of setting investment criteria for institution building and training programs.

These problems are addressed in this section and the following section. The goals of both are to discuss the application of conventional economic analysis to agroforestry issues and to suggest ways of extending these techniques in a manner consistent with the special technical and institutional context of agroforestry. This first section reviews and interprets the economic literature available on agroforestry, and considers, in turn, the nature of demands for forest products and services in rural areas in developing countries, the production system and market structure in which consumption takes place, and finally the results of specific agroforestry project benefit-cost studies. The following section continues with the issues raised and specifically evaluates the relevance of conventional project analysis techniques and methodologies. To the degree that established techniques are not appropriate to agroforestry, extensions that have been used or that are relevant are presented.

Aspects of supply and demand for forest products are the starting point in the discussion on the economics of agroforestry for two reasons. First is simply to lay out the variety and volumes of products and services likely to be of interest, and to consider the quality and quantity of available information. More important is the presentation of a view of forest production and consumption as taking place within an overall production system dominated by nonmarket agricultural activities. Approaches to valuation issues based on this system's view are then proposed.

DEMAND FOR FOREST PRODUCTS AND SERVICES

The intent of this approach to the economics of agroforestry is to emphasize the jointness of food and wood production and consumption by rural households in developing countries. Consequently it is somewhat arbitrary to distinguish between

supply and demand. More precisely this section will discuss production and consumption of forest products and services and the ways in which they contribute to the welfare of rural people. The resource allocation patterns necessary to support that consumption will be discussed later.

From the point of view of benefit-cost analysis, the appropriate measure of welfare from some good is willingness to pay (WTP). This concept has received extensive theoretical treatment and its application to project appraisal is thoroughly discussed elsewhere. In practice WTP for a good is crudely thought of as the area beneath its demand curve. Given a demand curve and an initial price and quantity, additional quantities of a good are valued by the increment to that area. Thus, in Figure 1 at price P_1, quantity Q_1 is demanded and willingness to pay is given by the crosshatched area. Should additional $(Q_2 - Q_1)$ units of the good become available, price would fall to P_2 and an addition to willingness to pay of area ABQ_2Q_1 would result. Intuitively, WTP is an expression of the total consumption benefit made possible by obtaining a quantity of a good at a particular price.

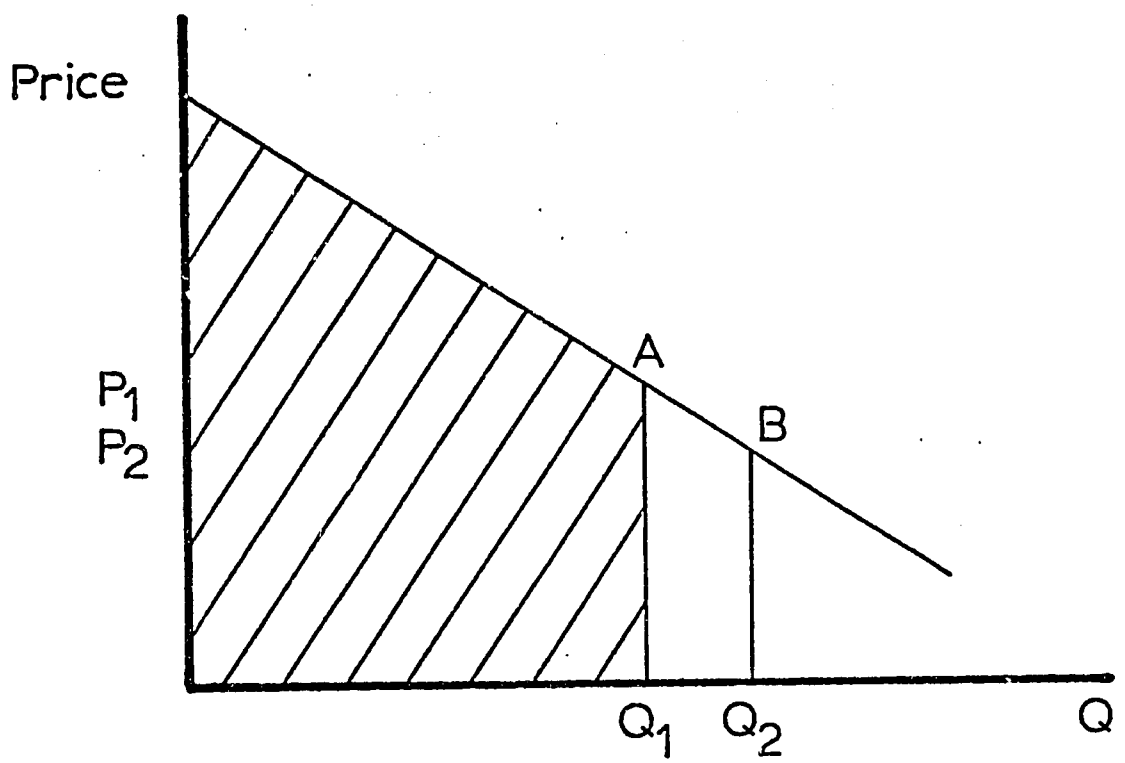
Similarly, the costs of an activity can be viewed as reductions in the availability of goods that are inputs to that activity. Thus, the seemingly arbitrary distinction between supply and demand of agroforestry activities can be seen as being based on somewhat more concrete division between production and consumption.

A. Consumption of Forest Products

Most attention to wood consumption in developing countries has focused on fuelwood which accounts for some 80 percent of all wood harvested in less developed countries (LDCs). At the same time, however, trees provide a number of other goods and services that are of value to rural people. These include building materials, fodder, and so-called "minor products" and services such as erosion control, crop protection and other amenities. From an economic perspective the most striking and problematic feature of these is the extent to which consumption takes place outside of a functioning market. Two implications of this absence of effective markets are that those prices which do occur are poor measures of value and that quantitites are seldom meaningfully recorded.

Consequently, WTP estimation for agroforestry project evaluation is more difficult than for conventional investment projects. The selection of shadow prices for wood and environmental services necessitates the use of one or more approximations which are discussed later. In order to select the most appropriate shadow pricing approach, it is necessary to consider the role of the consumption of wood in rural

FIGURE 1



communities. The most important aspects to consider are: the quantitites involved; the effects of changes in prices/costs and income; and the availability of substitutes.

Only a few general conclusions can be reached regarding the volume of fuelwood used in developing countries. One is the location specificity of consumption. This is in part a consequence of the extremely high transport cost of wood. Probably a more important source of the great variation in levels of consumption, however, is simply the multiplicity of functions which affect demand, only some of which have been identified. The large variation in levels of use has important implications for the development of policies on agroforestry. Most important is the need to develop strategies aimed at providing physical inputs and technical assistance to relatively small groups, such as individual farms or villages. At larger levels of aggregation, states or regions, there is a high likelihood of grouping households with widely differing wood consumption patterns. This is especially true of fuelwood-oriented projects where high transport cost, relative to unit value, reduces the potential for the establishment of large distribution and marketing schemes, at least for the supply of rural areas. The variability of consumption also heightens the need to gain an understanding of the levels of consumption in a particular location rather than relying on aggregate data at the national level. Similarly data from small areas can only be extrapolated with great caution. Unfortunately, available statistics are generally based on small surveys of short duration.

Despite the weakness of available statistics on fuelwood consumption some observations can be made. Table 1 shows estimated total and per capita fuelwood consumption for 114 countries and regions based on FAO statistics; estimates for consumption of wood in all other forms is also shown. As can be seen on a developing world basis, 80 percent of all wood is consumed as firewood or charcoal, compared with a figure for developed countries of 12 percent. In volume terms, average per capita annual consumption in LDCs is approximately 0.47 m^3 or 340 kg.

Table 2, based on FAO (1980), provides examples of the range of estimates of consumption within 10 countries. Sources of this variation include genuine variation over time and space, faulty survey design, and the inclusion of published "estimates" which are little more than guesses.

Among the conclusions that can be reached with respect to wood energy is a crude rank ordering of fuel preference (see Arnold, 1978). Roughly these correspond to economic concepts of income elasticity and substitutability. At the top of this list would be commercial energy sources (such as electricity) which are prized for their convenience but which are generally unavailable to the rural poor. A more practical

TABLE 1

ANNUAL FIREWOOD, CHARCOAL AND TOTAL WOOD PRODUCTION IN DEVELOPING COUNTRIES
(1980)

Country or Region	Population (million) Mid 1980	TOTAL PRODUCTION			PER CAPITA (m^3)		
		(000 m^3) Roundwood[1]	Firewood[2]	(000 MT) Charcoal[3]	All Wood	Firewood	Charcoal
Africa	473.1	434,152	384,885	6,942	0.92	0.81	0.01
Algeria	18.9	1,617	1,412	-	0.09	0.07	-
Angola	7.1	8,759	7,468	-	1.20	1.05	-
Benin	3.4	3,768	3,567	30	1.11	1.05	0.01
Botswana	0.8	781	729	-	0.98	0.91	-
Burundi	4.1	754	716	10	0.18	0.17	-
Cameroon	8.4	9,989	7,808	-	1.19	0.83	-
Central African Republic	2.3	3,014	2,485	-	1.31	1.08	-
Chad	4.5	7,665	7,215	334	1.70	1.60	0.07
Congo	1.6	2,182	1,380	-	1.36	0.86	-
Egypt	39.8	1,799	1,716	-	0.05	0.04	-
Equitorial Guinea	0.3	465	415	-	1.55	1.38	-
Ethiopia	31.1	24,330	22,894	153	0.79	0.74	-
Gabon	0.7	2,470	1,207	-	3.53	1.72	-
Gambia	0.6	874	864	35	1.46	1.44	0.06
Ghana	11.7	9,577	7,058	-	0.82	0.60	-
Guinea	5.4	3,538	3,008	-	0.66	0.56	-
Guinea Bissau	0.8	525	422	-	0.66	0.53	-
Ivory Coast	8.3	11,807	6,459	138	1.42	0.78	0.02
Kenya	15.9	27,364	26,200	1,512	1.72	1.65	0.10
Lesotho	1.3	293	293	-	0.23	0.23	-
Liberia	1.0	4,939	4,078	277	2.60	2.15	0.15

Table 1 con't.

Country or Region	Population (million) Mid 1980	TOTAL PRODUCTION (000 m^3)[1] Roundwood	Firewood[2]	(000 MT)[3] Charcoal	PER CAPITA (m^3) All Wood	Firewood	Charcoal
Libya	3.0	627	536	-	0.21	0.18	-
Madagascar	8.7	6,116	5,309	-	0.70	0.61	-
Malawi	6.1	10,098	9,731	5	1.66	1.60	-
Mali	7.0	29,419	29,150	-	4.20	4.16	-
Mauritania	1.5	632	588	-	0.42	0.39	-
Mauritius	0.9	29	11	-	0.03	0.01	-
Morocco	20.2	1,753	1,351	-	0.09	0.07	-
Mozambique	12.1	13,136	12,306	71	1.09	1.02	0.01
Niger	5.3	2,946	2,735	-	0.56	0.52	-
Nigeria	84.7	99,484	92,124	1,066	1.17	1.09	0.01
Rwanda	5.2	4,943	4,883	-	0.95	0.94	-
Senegal	5.7	2,816	2,335	100	0.49	0.41	0.02
Sierra Leone	3.5	7,796	7,638	823	2.23	2.18	0.24
Somalia	3.9	721	657	62	0.18	0.17	0.02
South Africa	29.3	15,961	7,000	-	0.54	0.24	-
Sudan	18.7	34,377	32,845	1,744	1.84	1.76	0.09
Swaziland	0.6	2,154	543	-	3.59	0.91	-
Tanzania	18.7	34,824	33,895	106	1.86	1.81	0.01
Togo	2.5	678	530	-	0.27	0.21	-
Tunisia	6.4	2,705	2,589	104	0.42	0.40	0.02
Uganda	12.6	5,788	4,360	106	0.46	0.35	0.01
Upper Volta	6.1	6,437	6,132	22	1.06	1.01	-
Zaire	28.3	10,280	8,020	-	0.36	0.28	-
Zambia	5.8	5,460	4,992	244	0.94	0.86	0.04
Zimbabwe	7.4	8,462	7,231	-	1.14	0.98	-

Table 1 con't.

Country or Region	Population (million) Mid 1980	TOTAL PRODUCTION (000 m^3) Roundwood[1]	Firewood[2]	(000 MT) Charcoal[3]	PER CAPITA (m^3) All Wood	Firewood	Charcoal
Asia	2343.4	993,602	811,958	2,716	0.42	0.35	-
Afganistan	15.9	8,248	6,731	-	0.52	0.42	-
Bangladesh	88.5	10,929	9,754	-	0.12	0.11	-
Bhutar	1.3	3,134	2,884	-	2.41	2.22	-
Burma	34.8	26,592	23,618	-	0.76	0.68	-
China[4]	976.7	224,628	156,568	-	0.23	0.16	-
Cyprus	0.6	97	22	1	0.16	0.04	-
India	673.2	225,835	206,055	1,569	0.34	0.31	-
Indonesia	146.6	157,684	133,022	104	1.08	0.91	-
Jordan	3.2	9	5	-	-	-	-
Kampuchea	6.9	5,132	4,565	-	0.74	0.66	-
Korea (DPR)	18.3	5,935	5,335	-	0.32	0.29	-
Korea (Rep.)	38.2	68,361	65,717	15	1.79	1.72	-
Laos	3.4	3,617	3,394	104	1.06	1.00	0.03
Lebanon	2.7	506	469	20	0.19	0.17	0.01
Malaysia	13.9	43,486	10,861	314	3.13	0.78	0.02
Mongolia	1.7	2,390	1,350	-	1.41	0.79	-
Nepal	14.6	13,596	13,036	20	0.83	0.89	-
Pakistan	82.2	18,949	18,369	-	0.23	0.22	-
Philippines	49.0	35,212	26,056	-	0.72	0.53	-
Sri Lanka	14.7	7,797	7,120	-	0.53	0.48	-
Syria	9.0	37	12	-	-	-	-
Thailand	47.0	38,131	33,134	528	0.81	0.70	0.01
Turkey	44.0	28,489	21,802	-	0.63	0.49	-
Vietnam	54.2	64,566	61,827	-	1.19	1.14	-
Yeman Dem Rep	1.9	252	252	42	0.01	0.01	-

Table 1 con't.

Country or Region	Population (million) Mid 1980	TOTAL PRODUCTION (000 m^3) Roundwood[1]	Firewood[2]	(000 MT) Charcoal[3]	PER CAPITA (m^3) All Wood	Firewood	Charcoal
Latin America	352.9	385,083	287,268	6,557	1.09	0.81	0.02
Argentina	27.7	9,866	5,796	368	0.36	0.21	0.01
Belize	0.1	125	79	-	1.25	0.79	-
Bolivia	5.6	4,630	4,197	16	0.83	0.75	-
Brazil	118,7	231,724	174,406	4,865	1.95	1.47	0.04
Chile	11.1	17,712	3,263	40	1.60	0.29	-
Colombia	26.7	42,832	39,778	419	1.60	1.49	0.02
Costa Rica	2.2	2,732	1,475	13	1.24	0.67	0.01
Cuba	9.7	3,151	2,766	57	0.32	0.29	0.01
Dominican Republic	5.4	189	180	-	0.04	0.03	-
Ecuador	8.0	6,349	4,629	318	0.79	0.58	0.04
El Salvador	4.5	3,296	3,196	21	0.73	0.71	-
Guatemala	7.3	11,231	11,072	-	1.54	1.52	-
Guyana	0.8	199	10	-	0.25	0.01	-
Haiti	5.0	5,018	4,779	82	1.00	0.96	0.02
Honduras	3.7	5,332	4,220	-	1.44	1.14	-
Jamaica	2.2	34	13	2	0.02	0.01	-
Mexico	69.8	12,200	5,855	106	0.17	0.08	-
Nicarauqua	2.6	3,169	2,289	-	1.22	0.88	-
Panama	1.8	3,010	1,671	-	1.12	0.93	-
Paraquay	3.2	6,720	4,308	151	2.10	1.35	0.05
Peru	17.4	5,418	3,430	10	0.31	0.20	-
Suriname	0.4	341	4	-	0.85	0.01	-
Trinidad and Tobago	1.2	97	22	2	0.81	0.02	-
Uruguay	2.9	1,564	1,322	87	0.54	0.46	0.03
Venezuela	14.9	9,144	8,508	-	0.61	0.57	-

Table 1 con't.

Country or Region	Population (million) Mid 1980	TOTAL PRODUCTION (000 m^3) Roundwood[1]	Firewood[2]	(000 MT) Charcoal[3]	PER CAPITA (m^3) All Wood	Firewood	Charcoal
Developing Regions	3169.4	1,812,837	1,484,111	16,215	0.57	0.47	0.01
Developed Regions	887.9	1,189,667	138,783	132	1.34	0.16	-
N. America[5]	251.6	579,859	93,881	-	2.30	0.37	-
W. Europe[6]	370.8	253,208	37,012	132	0.68	0.10	-
USSR	265.5	356,600	7,890	-	1.34	0.03	-
WORLD[7]	4057.3	3,002,504	1,622,894	16,347	0.74	0.40	-

NOTES: [1]Foundwood in cubic meters, includes all wood harvested.

[2]Firewood in cubic meters includes all hard and softwood directly burned and wood converted to charcoal. Conversion from wood to charcoal is made by using a factor 1 metric ton equals 6 cubic meters.

[3]In metric tons - includes no quantities reported or negligible amounts on per capita basis.

[4]Peoples Republic and Taiwan.

[5]Includes United States and Canada.

[6]Includes Austria, Belgium, Luxemburg, Denmark, Finland, France, German Federal Republic, Greece, Iceland, Italy, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, Yugoslavia.

[7]Totals include those countries and regions listed individually.

TABLE 2

RANGES OF PER CAPITA FUELWOOD CONSUMPTION ESTIMATES FOR SELECTED COUNTRIES

Country	Low	High	Final 1980 FAO Estimate
	(m^3/person/year)		
Burundi	0.218	1.22	0.1456
Chad	0.825	1.1519	1.1519
Ethiopia	0.654	1.01	0.6158
Gambia	0.470	1.20	1.0852
Senegal	0.006	0.577	0.3066
India	0.188	0.380	0.2738
Republic of Korea	0.179	1.318	1.04
Nepal	0.330	1.00	0.8991
Bolivia	0.002	0.684	0.7366
Columbia	0.119	0.742	1.3849

SOURCES: P.A. Wardle and F. Pontecorvi, "Special Enquiry on Fuelwood and Charcoal" (FAO: Rome), February 1981.

FAO Yearbook of Forest Products, 1980 (FAO: Rome), 1982. p. 60.

alternative, but still beyond the means of most, is kerosene. Both kerosene and electricity require substantial cash outlays, access to distribution systems, and investments in stoves.

More in line with traditional usage is charcoal which is very often the primary form of wood energy usage in urban areas. Charcoal is often a preferred form due to its high energy content per unit weight, smokeless burning and other characteristics. In rural areas charcoal is likely to be relevant when the remoteness of wood sources outweighs conversion costs.

Charcoal appears to be followed in preference by wood. Charcoal is produced from wood in a variety of ways, with the bulk of LDC output coming from small-scale artisanal producers. Typical technology involves burning wood in earthen mounds and results in large losses of energy. Despite this technical inefficiency, the reduction in weight per unit energy enables charcoal to be transported economically for greater distances at lower costs (Earl, 1975).

In addition to wood a variety of agricultural residues and animal dung are significant sources of energy. Widely quoted examples are millet stalks in Upper Volta and cattle dung in South Asia. While these materials apparently provide a technically acceptable fuel the negative consequences of their use as fuel has been extensively discussed. Burning of these residues limits the volume available for composting and use as fodder or soil conditioners and may have long- and short-term consequences for agricultural output.

While concern for these impacts is well-founded there are several important points to consider with respect to attempts to replace residues with wood from managed stands. One is that, aside from their technical substitutability for wood, residues are available at little cost or effort to most all rural people and in some places are thoroughly integrated into the domestic energy economy. For example, Ernst (1978) noted that,

> ...women prefer to use, as much as possible, millet stalks instead of wood. The stalks weigh no more than wood, and they are found in fields next to the homes. There is no need for stacking, unlike wood, and the millet stalks can be collected either several times a day, for each meal, or as needed.

In addition the negative consequences of residue use are extremely difficult to quantify in economic terms. In fact, it is conceivable that diversion of substantial proportions of residues from the food production system is a sustainable practice. This

is in part a technical issue that requires analysis by agronomists and soil scientists to supplement economic and analysis. (Some approaches to these issues will be discussed below.

B. Income Elasticities of Demand

It is generally presumed that increases in income will be associated with shifts toward more highly preferred energy sources. Unfortunately there appear to be very few quantitative studies of income elasticities for various fuels. To some extent this can be attributed to the difficulty of obtaining meaningful data on prices, quantities and incomes, given the extent of nonmarket production and consumption of rural populations.

Several studies of price and income elasticities of demand are reviewed in World Bank (1981). Estimated income elasticities for total energy (the percentage change in consumption that results from a one-percent change in income) range from 0.256 to 0.8. Higher elasticities, up to 1.29, were found for commercial fuels such as gasoline. Lower elasticities, in some cases negative, were found for noncommercial fuels including firewood. As regards price elasticity, the general conclusion of the Bank study was that in terms of noncommercial energy sources, physical availability was far more important than price in predicting consumption.

Income elasticities and substitutability among fuels are important data for development of an energy and forestry strategy, as well as for the selection of an investment portfolio. This is especially true given the long-term nature of forestry projects. For example, if incomes are expected to rise rapidly, the degree to which people will shift to nonwood fuels is critical to the financial and economic viabilty of fuelwood plantations.[1]

An alternative approach to the economic concept of demand for wood, which has received considerable attention from forest planners, is the notion of needs. An example of this approach is the FAO Fuelwood Map and a forthcoming FAO monograph. According to the Fuelwood Map Study, approximately 2 billion people

[1]One possible example of the importance of the income elasticity of demand for fuelwood is the Korea Village Fuelwood Plantation Program. This program has received considerable attention and has been promoted as a model for community forestry projects. While planting targets have been met and survival rates high, there has also been a continuing shift to alternative energy sources such as domestically available coal and hydroelectric power. Thus, in addition to good project design, the success of the Korean program can probably also be attributed to the general economic development of the country and an associated decline (or at least slow growth) in demand for fuelwood. See FAO (1982).

depend on fuelwood and traditional fuels as their domestic energy sources. Approximately 200 million are unable to satisfy their "needs" and 1.05 billion are living in situations in which they are overexploiting the resource base. The needs approach assumes some minimum level of fuelwood consumption necessary to accommodate some basic standard of living. Needs are presumed to be inelastic with respect to own price or cost, incomes or the cost of substitutes. As discussed above this does not seem to reflect accurately the case of forest products. Thus, while useful for illustrative purposes, the needs concept has limited usefulness for analysis and investment planning.

Unfortunately given the data gaps indicated above the most practical approach to handling fuelwood demand, especially for the purposes of projections into the future, is what has been the general practice to data. That is, to make the assumption that per capita levels of consumption will remain constant. This assumption, supplemented by an admittedly arbitrary factor for fuel substitution, was employed in the World Bank's Renewable Energy Task Force Study's Fuelwood Supply/Demand Analysis. This analysis concluded that an annual plantation establishment program, on a worldwide basis, of 2.6 million hectares could be justified. This would require a fivefold expansion of current efforts. With the development of a more reliable data base the preparation of better estimates of fuelwood demand should be possible.

Despite the divergent approaches of the World Bank and FAO studies, the most significant conclusions and policy implications are similar. Both conclude that fuelwood scarcity is a major problem in a large number of countries. Consistent with the FAO findings is the Bank's estimate that US$3,027 million (1980) investment in fuelwood production projects would be required by the year 2000 in order to make annual growth equal to fuelwood harvest. Aside from the magnitude of this requirement, particularly troubling is the inability of LDC forest management agencies to plan and justify projects, and to implement this level of investment. Along these lines, a subsequent World Bank-UNDP (1982) study of preinvestment requirements for the development and utilization of new and renewable sources of energy concluded that $448.9 million worth of preinvestment work is required over the period 1982-90, in order to develop an institutional capability in community forestry in developing countries. This amounts to 15 percent of estimated total investment requirements.

C. Demand and Production

While data on firewood usage is uncertain, information on other uses of wood is even more fragmentary. The availability of substitutes for wood in these uses is unclear and seems to have received little treatment in the literature. Draper (1977)

identifies three categories of solid wood products that are important at the village level: building poles and sawn wood, joinery and furniture, and farm implements. With respect to building materials, he points out that in many areas the most durable timbers in natural forests are already severely depleted. Since these durable species are slow-growing, their replacement by fast-growing species may require development of drying and preservation techniques, and improved house design.

He also points out that at low levels of income, considerable latent demand for basic low-cost joinery and furniture can be presumed. With the availability of low-cost wood supplies, small-scale carpentry shops have developed to meet this demand, for example in Nigeria and Malawi. Aside from wood supplies, full development of this potential requires training, credit for simple equipment and tools, and small-scale mills for the conversion of roundwood into dimension lumber.

The potential market for wooden farm implements is also typically large in developing countries, and includes hand tools and animal drawn carts and wooden farm implements such as plows and cultivators. An additional use of wood is for fencing material which can serve as an input to both crop and wood production by restricting uncontrolled browsing by animals. The high probability that there is significant pent-up demand for solid wood products at the village level mitigates concern over future demand for fuelwood. It also suggests that in cases of uncertainty over future demand patterns, it may be desirable to establish multiple-use species with characteristics desirable for use as fuel or as solid wood. This appraoch was used in the Korean Village Fuelwood Plantations Project (FAO, 1979).

One output of trees that often serves as an intermediate input to food production is fodder. For example in Nepal 74 percent of all livestock feed is derived from forests and grasslands (World Bank, 1978). A study by the International Livestock Centre for Africa (ILCA, 1980) indicates the potential significance of agroforestry as a source of animal fodder. The authors analyzed a number of project designs and found that the ratio of wood and browse (weight basis) ranged from 1:1 for Atriplex spp. to 3:1 for Acacia Senegal. On a value basis (using shadow prices based on world prices for animal feeds), the ratio of feed value to wood value ranged from 10:1 for Atriplex spp. to 1:10 for Acacia Senegal.

In addition to firewood, solid wood products and fodder, agroforestry provides a number of so-called minor products. These include fruits, mushrooms, and wildlife species (Poulsen, 1982). In some locations these products may be highly valued and make important contirbutions to nutrition and consumption. Table 3, based on the World Bank Agricultural Sector Survey of Peru (1975), indicates the significance of

TABLE 3

QUANTITY AND VALUE OF "MINOR" FOREST PRODUCTS IN PERU
(1969)

Output	Quantity	Value* 000 Soles
Rubber	493,789 kg	8,888
Oil (Perfume Base)	1,492,949 kg	1,045
Resin	7,025 gallons	210
Chewing Gum Base	178,251 kg	1,871
Plastic Base	773,379 kg	1,871
Peeled Brazil Nuts	1,176,533 kg	21,117
Ornamental Plants	740,438 units	281
Hides and Skins	272,447 units	19,668
Wild Game Meat	5,155 tons	79,947
Total Minor Products		134,841

SOURCE: World Bank, Agricultural Sector Survey Peru. Vol. II, Annexes. March 14, 1975. Report no. 549a-PE.

NOTE: * = U.S.$1 = 38.7 Soles.

"minor" forest products. The total market value of the nine classes of products listed was 134.8 million sales (US$348,400 at 1975 prices). This amounts to more than one-third of the total value of the country's sawn wood production.

A final category of forest products relevant to agroforestry is cash income from the sale of wood, fodder and other products. This is of major importance for a number of successful agroforestry projects such as the Philippines Small-holder Tree Farming Projects in which farmers sell pulpwood, and a series of projects in India which sell fuelwood and timber. These tend to be cases in which markets are readily available. Trees may be raised exclusively as a cash crop and constitute a sole source of income. Gum arabic production is an example of a more traditional use of trees to generate cash income.

The services that are provided by trees are often given as one justification for agroforestry projects. Some of these services such as soil and crop protection are reasonably well documented in physical terms. Less easily measured are the economic aspects of these services. One important economic dimension of these services is the extent to which services can be captured by individuals. Trees less closely integrated with crop production or on public lands may provide other services which are of a public-good nature. In these cases individuals are less likely to exert an effective demand for these benefits.

Certain ways of integrating trees and agriculture generate service benefits that can be appropriated by individuals. This would seem to make them more likely to gain acceptance. For example, shelterbelts have been shown to have a measurable impact on crop yields and are valued by farmers for their effects. Similarly, interplanting systems seems to have salutary effects on yields.

In sum, the following picture of the demand for forest products emerges. In volume terms the dominant use is for energy production. In this regard there appear to be substitutes available that are both more and less highly preferred. Factors determining the extent of substitution are cost (in terms of price and/or effort) for wood and the alternatives. The importance and availability of substitutes for other uses of wood is generally unknown. The environmental services of trees may be of significant value and are often of a public-good variety. Integration of trees and agriculture can, to some extent, at least privatize these benefits.

An important theme running throughout the list of outputs from trees are connections to the overall productivity of the food system. Examples of this are the possible negative consequences of burning residues in lieu of wood, and the crop and soil protection services of standing trees.

SUPPLY AND MARKET STRUCTURE

A. Resource Allocation Patterns

A basic problem in valuing inputs to investment projects is judging opportunity costs. That is, what is the value foregone in the next best opportunity by virtue of allocating resources to a proposed activity? In normally functioning markets, this question can be approached by considering the supply curve of the goods in question. As with the case of demand and consumption of wood, conventional markets do not typically occur for wood products in developing countries. The result is that costs are difficult to measure. Thus, project analysis must develop indirect methods of assessing the cost to society of expanding wood production. Asking this question for agroforestry requires consideration of a range of issues, including traditional wood procurement, the requirement of a proposed system, and the limitation posed by other activities and objectives of the farm household. Certainly no two situations are alike but there are sufficient similarities to allow a general economic description of subsistence and semisubsistence production. The major feature of this overall production system is the paramount significance of food crop cultivation. With regard to wood procurement, by far the most important theme in the literature is the open access, common property nature of the resource. Other elements of the production system that have implications for the design and implementation of agroforestry projects are the sexual division of labor, the low level of technology, and the generally low level of productivity. Institutions external to the rural household also affect the viability of organized wood production. Among these are administratively determined stumpage prices for natural stands which compete with plantations, and the existence of mechanisms to deliver technical assistance to farmers.

Extensive literature has considered the nature of food production in developing countries. The purpose of this discussion is not to review it in detail but to highlight major issues which affect the integration of additional activities into the farming system. As a unit, a subsistence or semisubsistence household can be viewed as primarily pursuing the objectives of maximizing food production and of avoiding risk. A variety of other objectives may also be important including noneconomic ones. There may be competing objectives and different priorities within the unit. Objectives are sought subject to constraints on the resources available to the family, principally labor, land, and capital. Thus a family, for example, must allocate its total amount of available labor to the tasks required by crop production, domestic chores including wood collection and nonfarm employment. Similarly the family must allocate land to

grain, vegetables, trees, livestock or fallow, subject to the amount of land physically and institutionally available.

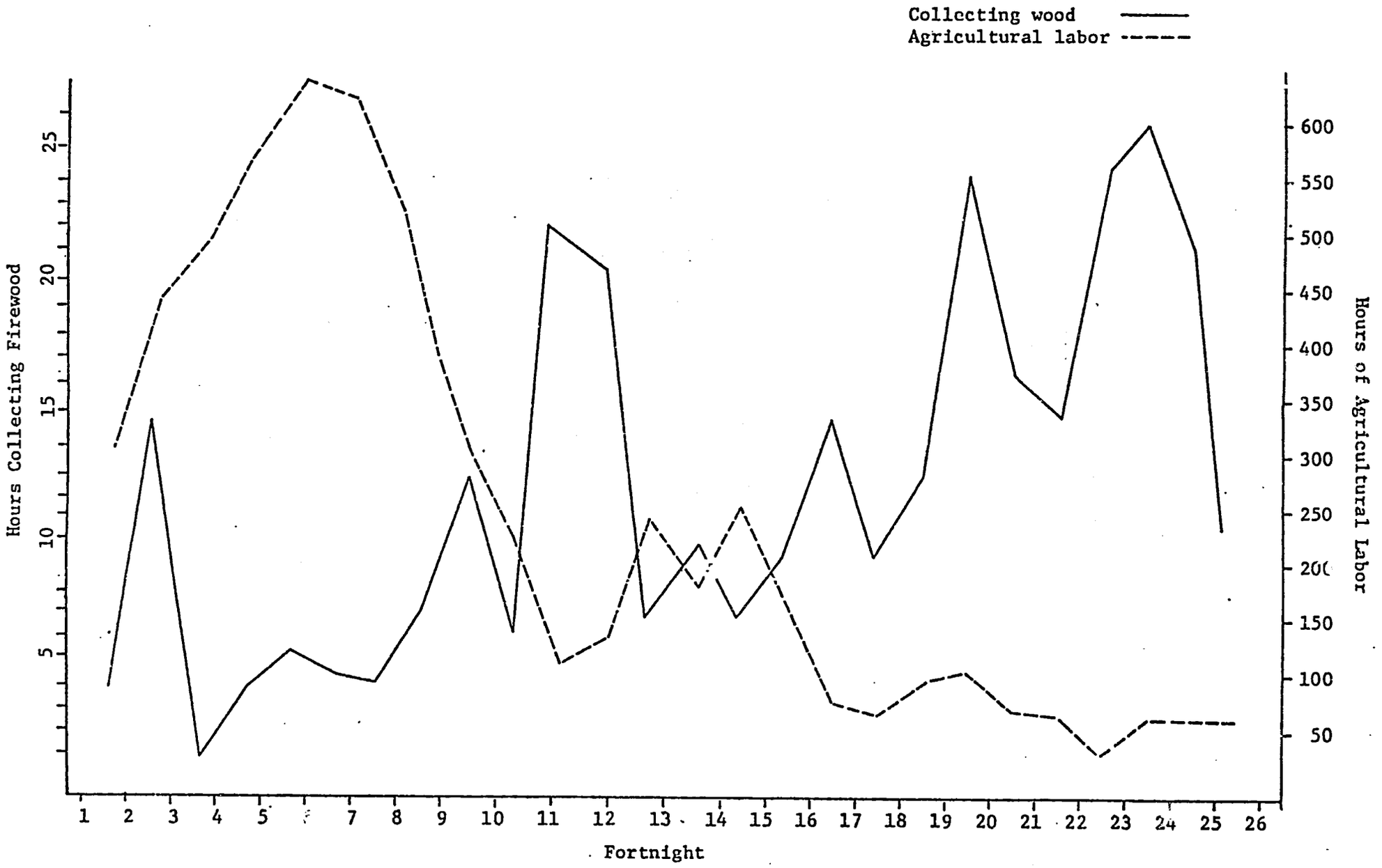
While these allocation decisions take place in physical and cultural circumstances that widely vary, certain common features are present. One frequently important feature of agricultural production is seasonality of labor requirements. For example, it has been repeatedly observed that in Subsaharan Africa peaks in labor requirements occur at planting and harvesting. At other times in the year the labor force does not appear to be fully utilized. In South and Southeast Asia the availability of land rather than labor is more typically a constraint and accommodating peak labor demands does not present a major problem. Intraseason time constraints have been found to be of critical importance in the introduction of agroforestry systems. For example, Winterbottom (1979), in reviewing the experience of woodlots in Upper Volta noted the coincidence of planting times for food crops and tree seedlings. Seedlings scheduled for planting by mid-July were not established on time because farmers were tied up with crop planting and weeding until late July. Consequently seedling survival was low. Logistical problems also contributed to mortality.

While wood itself has been treated as a free good, its collection, storage and use do incur opportunity costs for the farm family. As a reaction, ways of minimizing these costs seem to have been developed. For example, traditional stoves while inefficient are essentially costless, and consumption seems to focus on small branches and dead trees that can be collected with hand tools or with no tools at all. Less obvious ways of minimizing costs are the apparent scheduling of wood collection around seasonal labor peaks and the division of labor among family members.

Figure 2, based on Delgado's (1979) data from Upper Volta, compares time allotted to fuelwood collection with time devoted to crop production over the period of a year. Clearly agricultural labor (scaled on the right axis) absorbs far greater quantities of labor. What is of interest, however, is the generally negative correlation between fuelwood collection and agricultural labor. Several factors contribute to this ability to compress fuel collection labor requirements. During the wet season, firewood gathered in the bush is too wet to burn. This requires wood collection prior to the rains. Following the harvest, millet stalks are readily available for use as fuel. Ernst (1978), also in Upper Volta, noted that the use of millet stalks is a seasonal phenomenon. This seasonality of wood and residue collection, and the extent to which it is integrated with inflexible crop production requirements, may have major implications for the addition of intensive wood production to family farms. This issue is discussed in the following section with respect to valuing family labor.

FIGURE 2

HOUSEHOLD LABOR ALLOCATED TO COLLECTING FIREWOOD AND TO AGRICULTURAL LABOR BY FORTNIGHT



SOURCE: Delgado (1979)

Normative restrictions on the type of work appropriate for men and women also condition the character of the production system. Often animal husbandry and staple grain production are male tasks, while other crops and domestic chores are female responsibilities. Similarly certain tasks fall to children and the elderly who may lack the skills or strength for more exacting or arduous pursuits. Thus the priority for different innovations may vary among family members.

For example, when responsibility for wood collection falls on women and children, it may not be reasonable to expect men to assume responsibility for planting and protecting trees. Similarly, men are less likely to purchase more efficient stoves when women will be the principal beneficiary of the innovation.

A feature of wood collection that has attracted considerable attention is the degree to which women bear the burden in time and effort expended. Essentially all studies of household energy economies in developing countries emphasize this point. Aside from women, children are often required to devote significant amounts of time to wood collection. This age and sex division of labor has important economic and social dimensions that are discussed in the following section where valuing family labor and merit wants are discussed.

It has also been observed that time spent collecting wood is often combined with other activities such as gathering wild foods and socializing. Quantitative information regarding total time spent collecting wood, and the proportion that can be attributed to other pursuits is seldom available. A relevant consideration is the amount of time that would be required for these other activities if wood collection were not necessary. This is an empirical question that requires intimate knowledge of the local culture.

Other ubiquitous characteristics of agriculture in developing countries are the low level of technology and the limited availability of capital. Mechanization is confined to the most rudimentary hand tools and limited knowledge of improved techniques. Restricted access to capital frequently retards the adoption of more advanced technology. Poor capital markets discourage saving and investment, leading to a situation in which the risk avoidance is a high priority.

Risk aversion has been a major topic in the literature on less developed country food production. Given the predominance of low levels of output, it is essential that families select farm management strategies that guarantee subsistence. This is true even if these strategies rule out the possibilities of higher levels of consumption if there is a chance of not achieving some minimum level of production. The need to minimize risk has several major effects. One is to discourage experimentation with new ways of doing things. Another is to limit the choice of possible farm strategies.

For example, if farmers view the production of a minimum amount of a staple food crop as essential, they may be precluded from other more profitable ventures by virture of the resources tied up in food production. The urgency of providing for current needs is also presumed to be reflected in a high rate of time preference (discount rate). The need to reserve current resources requirements for subsistence can inhibit or prevent the introduction of activitie such as family woodlots which in the long run would result in significant resource savings.

Superimposed on this system of subsistence food production are a number of subsystems including wood production and/or procurement. Just as with food production, wood production will vary from one situation to the next, though major patterns are discernable.

B. Forest Production

Historically naturally-occurring wood resources have been owned in common, with right to essentially unlimited access held by everyone. Resources showing this characteristic (such as fisheries, pasture land and fresh air) have been thoroughly discussed in economic theory. The likely consequences of common property are overconsumption, inadequate investment, and a smaller than optimal stock. Overconsumption results because if one refrains from consumption, there is no assurance that everyone else will and the private costs of obtaining wood (essentially labor in collection) are less than the social costs of collection plus the other resources consumed in maintaining the natural stand. Underinvestment results for similar reasons: basically if privately costless wood is available, why devote costly resources to its production? The combined effect of overconsumption and underinvestment is a stock of less than the desirable size. This is an especially significant problem for a resource, such as a forest, which generates positive externalities related to the size of the stock. Obviously this disinvestment occurs over an extended period of time and may not constitute an urgent problem until the stock is near depletion.

Not all wood production in traditional systems consists of collection from unmanaged natural stands. There are numerous examples of the cultivation of trees, of the traditional integration of trees with agriculture and the pollarding of trees for sustained production. The overall role of these systems in providing wood and forest services is unknown and requires investigation. These systems are more representative of what has come to be proposed as models for more formal agroforestry.

No single definition of agroforestry is broad enough to cover the range of perceptions of agroforestry held by various observers while also being sufficiently

precise to clearly distinguish agroforestry from conventional land use systems. One accepted characteristic is some sort of integration: spatial, temporal or both of annual crops and tree crops. As such, agroforestry can be interpreted as a special case of the multiple-use concept that has similarly evaded a satisfactory analytic definition. An economic interpretation of multiple use was first proposed by Gregory (1955) and has been related to agroforestry by Filius (n.d.). The approach builds on the classic microeconomic analysis of the multiproduct firm and is illustrated in Figure 3. Here it is extended to incorporate the insights of the theory of the farm household as proposed by Nakajima (1969), Hymer and Resnick, (1969), Wharton (1971) and others.

In Figure 3 the axes show the physical quantities of output of goods X_1 and X_2 produced by a given firm. The curve AA', known as the production possibility frontier, is the locus of the maximum possible combinations of food and wood that can be produced by that firm given a certain level of resources. Similarly curve BB' is the production possibility frontier associated with another larger level of resources. For example, AA' might be associated with input of one man-year of labor and BB' with two man-years of labor. The shape of the production possibility curve describes a process in which expansion of one output lowers output of the other good, at a rate (known as the marginal rate of transformation) which varies along the curve.

The slope of the dashed isorevenue line represents the relative prices of the two goods -- the rate at which the goods can be exchanged in the marketplace. As usual, the maximizing combination of outputs is such that the marginal rate of product transformation is equal to the price ratio. Graphically this is point Z, where the isorevenue line is tangent to the production possibility frontier. Hence the profit maximizing firm will produce X_1^* of X_1 and X_2^* of X_2. Only if there is no tangency between the production possibility frontier and the isorevenue line, will it be rational to specialize in one good or the other. This could occur if one good had no, or very small, market value.

In the context of agroforestry, Figure 4 can be interpreted as representing the variety of combinations of tree and food crops open to the cultivator. At each extreme are pure monocultures of either forest or crop production. Intermediate combinations, such as intercropping with various espacements are represented by points along the curves CC' or DD'. The shape of the production possibilities frontier will depend on the biotechnical nature of the crops and trees, and the extent of competition and complementarity between them. The extremes of each frontier show the possibility that trees and agriculture are not competitive but may be complementary. For example, even pure stands of tree plantations will generate some food unless

FIGURE 3

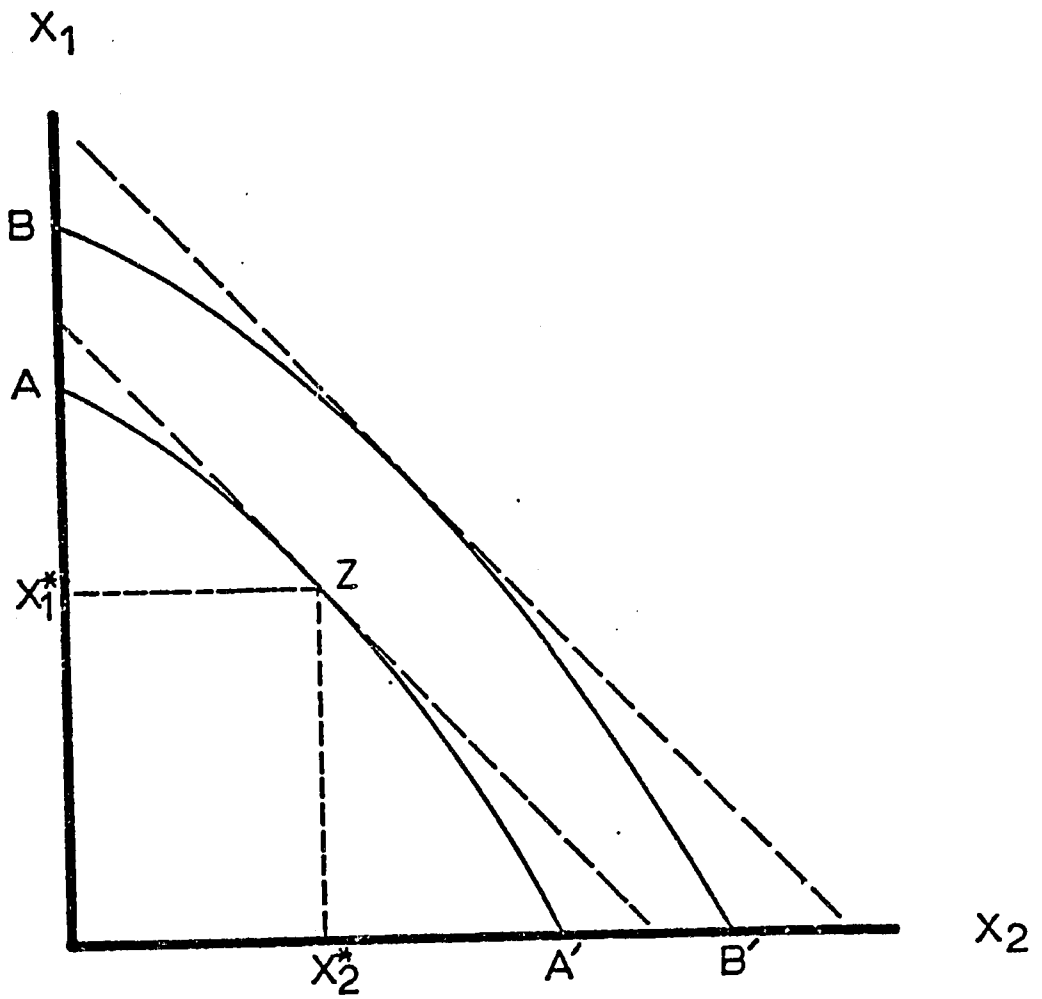
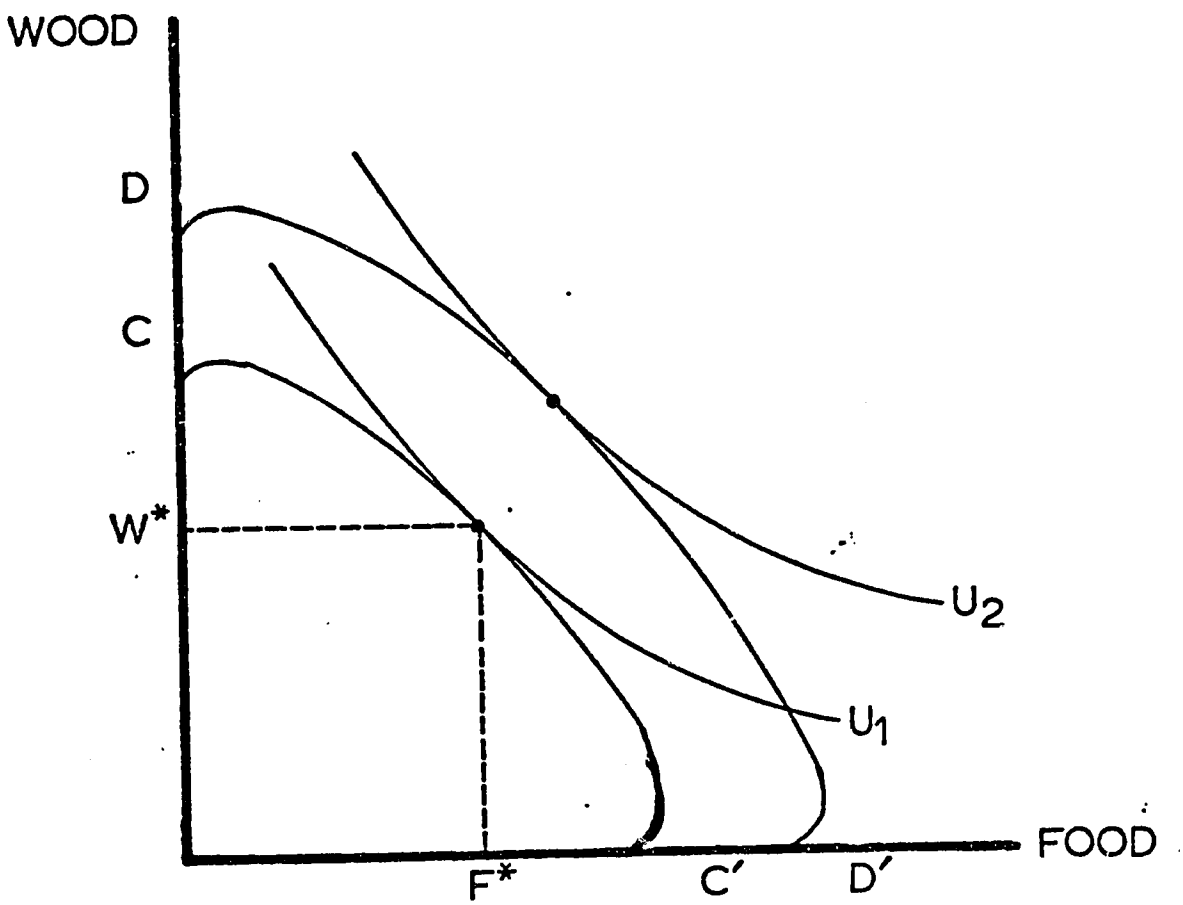


FIGURE 4



measures are taken to prevent bees, for example, from producing honey. To produce absolutely no food would require diversion of resources from wood production to insect control and would lower output of both food and wood.

In the case of agroforestry, where market transactions do not occur, the optimal combination is not given by relative prices. Instead the subjective valuation of wood and food by the farm family is shown in Figure 4 by indifference curves U_1, U_2. The tangency of the production possibility frontier and the family's indifference curve thus define the optimal combination, for example F* and W*.

Unfortunately little, if any, work has been done to estimate production possibility frontiers for agroforestry systems. Similarly the shape of indifference curves is difficult to determine. Empirical research in other applications of the theory of the farm household has focused on estimation of factor demand functions (Barnum and Squire, 1979) and could provide the basis for examination of agroforestry systems. Even in the absence of empirical data, consideration of essentially any plausible combination of production processes and utility functions suggests that at least some integration of crops and trees will be desirable.

C. Integrated Wood and Food Production

In reality the choice of outputs is not limited to only food crops and wood but includes a whole range of alternative crops, fuels, harvests from natural forests and nonagricultural activities. In addition, perceptions of the risks associated with various activities would need to be reflected in attempts to describe an actual production system and to interpret the decisions made by families. The value of such research would be severalfold. It would help to establish the economic nature of the underlying production technology and make explicit the choices forced by farmers and policymakers. It would also help to discern the factors that go into farmers decision making with regard to their subjective valuation of wood products vis-a-vis food crops and other outputs. From the point of view of project appraisal, given an estimate of the production function and the observed combination of outputs, shadow prices could be estimated for some nonmarket benefits.

The institution of more formal agroforestry into rural production systems will alleviate the need for some resources currently devoted to forestry, increase the need for others and require reallocation of other resources. The actual requirements of any system will vary along a number of dimensions. These include the extent of integration of trees and crops, the degree of orientation toward market or domestic production, and the role of family or community labor. The basic requirements are essentially the same as for food production: land and labor. The land requirements of

agroforestry projects is an elusive concept given the possibility of intercropping and the use of different espacements. Trees may also be established on field borders so as to not reduce land available for crops. It is often suggested that trees may be grown on land unsuitable for crops. In practice the fertility of land allocated to agroforestry has been a problem for some projects. For example in Upper Volta, Winterbottom (1979) observed that fast-growing exotics require land of the same fertility as food and cash crops. This discouraged participation by small-holders without access to surplus land.

Labor requirements for agroforestry projects also vary widely depending on the intensity of wood, crop production and other uses. A major consideration is that trees, especially as seedlings, often require the same treatment as agricultural crops, in terms of types of care and timing. Therefore, there is high potential for competition for scarce labor during peaks in the agricultural cropping cycle. This conflict will be particularly severe during the establishing phase of agroforestry projects before trees come to be of harvestable age on a continuous basis.

In addition to actual planting requirements, labor requirements for protection (mainly from poaching and grazing animals) and maintenance can be high. For example, in India one guard can protect 20 hectares which on an annual basis amounts to approximately 18 man-days per hectare (Srivastava and Pont). It is not clear from the literature how protection requirements change as plantation size decreases. In some areas protection is only required during certain portions of the year.

Maintenance requirements, principally weeding which provides protection from fire and adds to growth, vary with project design and over the life cycle of the project. In monocultures of trees, weeding requirements can be substantial in the early years of the project, and diminish as crown closure occurs. With intercropping, weeding requirements are shared jointly with crop production and may present less of a burden.

Probably the most significant resource required for agroforestry projects is the time required to allow the tree crop to mature. Only limited attention has been explicitly given to time as an input in agroforestry projects. One exception is the work of Hosier and Gelder (1982) which reviews the theoretical literature on the optimal age of harvest and presents data from Kenya on actual consumer preferences. They point out that foresters generally prescribe traditional rotation lengths based on production of large diameter sawtimber. Their observations, however, suggest that consumers prefer smaller diameter wood that is more easily handled, harvested and burned. In essence their analysis suggests that the value of wood changes with diameter (age) and that for use as fuelwood value peaks at relatively small sizes (early ages). Therefore,

if correct wood values and discounting procedures are employed, much shorter rotations are found to be optimal. In addition, shorter rotations allow tighter espacements and different choices of species.

SUMMARY OF AGROFORESTRY BENEFIT-COST ANALYSIS

A. Introduction

Only a small number of well-documented benefit-cost studies of agroforestry or social forestry projects are available. Those that have been prepared can be divided into two categories, ex ante and ex post, depending on whether the analysis was conducted before or after the project was initiated, respectively. The majority of available studies (75%) are ex ante. Seventy-eight studies are summarized in Table 4, which gives the source of data, the location of the project, the name or description of the project and the approximate date of initiation or analysis (when available), the estimated present net worth (PNW) of the project (and the associated discount rate), the internal rate of return (IRR), the accounting perspective (F or E for financial and economic respectively), and notes giving the most important features of the project or analysis. Asterisks refer to ex post studies.

It is necessary to use some degree of caution in comparing the results of these studies. Some were done for illustrative purposes only and averaging rates of returns for projects of vastly different size will not provide good estimates of expected returns. Nevertheless several general observations can be made. These relate to profitability and its apparent determinants, the quality and appropriateness of the analytic methodology and, related to methodology, the treatment of nonwood values.

B. Profitability

The average internal rate of return (IRR) for 43 of the projects summarized in Table 4 was 19.5 percent. This is shown on a worldwide and regional basis for ex ante and ex post analyses in Table 5. While overall, agroforestry projects appear extremely profitable, this is in part the result of the inclusion of several irrigated intensively managed plantations in India yielding IRR's above 70 percent.. When these are excluded, average ex ante returns are 14.8 percent.

The most striking result of this analysis is the difference in average ex ante and ex post profitability between Asia and Africa. Overall, the agroforestry projects in Asia earned 25.6 percent while those in Africa only 9.1 percent. This is even more striking on an ex post basis where Asian projects averaged IRR's of 27.4 percent. Although only one ex post evaluation of African agroforestry is available, its return was a very low 2.5 percent.

TABLE 4

PROFITABILITY OF AGROFORESTRY PROJECTS

Region: Africa

Reference	Country	Project Name and Description	PNW (r) (per hectare)	IRR(%)	Type of Analysis	Notes
32	Kenya	Fuelwood plantations (per hectare) p. 30 (High to Medium Rainfall)	Ks-3046 (10%)	4-1/2	F	Average unit costs, 10 yr rotation price = Ks 15/m^3
			Ks-2040 (10%)	7-1/2	F	Average unit costs, 10 yr rotation price = Ks 20/m^3
		Shamba Plantation	Ks-1588 (10%)	7-1/2	F	Average unit costs, 10 yr rotation price = Ks 15/m^3
			Ks-582 (10%)	9-1/2	F	Average unit costs, 10 yr rotation price = Ks 20/m^3
		Fuelwood (Medium to low rainfall) p. 39	Ks-1446 (10%)	3-1/2	F	Assumes lower costs that can be achieved through better management and wage policy changes 15 yr rotation price = Ks 15/m^3
			Ks-1042 (10%)	6	F	price = Ks 20/m^3
		Fuelwood/fodder/hondey (same as above)	Ks-1073 (10%)	13	F	price = Ks 15/m^3
			Ks-1477 (10%)	13	F	price = Ks 20/m^3
		Industrial fuelwood (Leuceana leucocephala)	Ks-952 (10%)	14-1/2	F	High Rainfall price = Ks 15/m^3
			Ks-1509 (10%)	12	F	High Rainfall price = Ks 20/m^3
			Ks-670 (10%)	8	F	Medium Rainfall price = Ks 15/m^3
			Ks-299 (10%)	9	F	Medium Rainfall price = Ks 20/m^3
37	Upper Volta	Ouagadougou Greenbelt	CFA-294,000 (12%)		F	Without intercropping.
			CFA- 50,000 (12%)		F	With intercropping
2	Nigeria	Taungya Department G. Arborea (1980)	₦ 2,489 (8%)		F	See Ball (1977) for model budgets, relative price changes have made all systems more profitable since earlier (1975) studies
		Traditional	₦ 1,942 (8%)		F	
		Direct Planting	₦ 1,639 (8%)	18	F	
		Departmental T. Grandis	₦ 464 (8%)		F	
		Traditional	₦ 8 (8%)		F	
		Direct Planting	₦ 182 (8%)	6.6	F	

con't. Profitability of Agroforestry Projects—Region: Africa

Reference	Country	Project Name and Description	PNW (r) (per hectare)	IRR(%)	Type of Analysis	Notes
27	Nigeria	Taungya Departmental Guelinal (pulp) (n.d.)	U.S.$ 1,445 (8%)		F	
		Departmental Guelinal (sawtimber)	U.S.$ 1,165 (8%)		F	
		Departmental Terminalia	U.S.$ 345 (8%)	> 10	F	
		Traditional Teak	U.S.$ 890 (8%)		F	
		Traditional Mahogany	U.S.$ 365 (8%)		F	
30	Nigeria	Shelterbelts Dalbergia Sissoo	₦ -86.33 (6%)		F	Without crop protection benefit (fuel only)
			₦ 21.53 (6%)		F	Crop protection only no harvest of wood
			₦ 635.38 (6%)		F	Wood and crops, low value crops
			₦ 876.83 (6%)		F	Wood and crops, high value crops
18	Tanzania	Taungya - Wood only (1978)	Tsh 13,200 (5%)		F	Value of all future rotations, no
		Intercropping & two yrs. of food crop	Tsh 25,600 (5%)		F	Labor cost for subsistence agriculture
		3 yrs. food, 2 yrs. intercropping, 24 yrs. rotation	Tsh 36,400 (5%)		F	Full cost charged for payed labor
		5 yrs. food, 3 yrs. intercropping, 24 yrs. rotation	Tsh 47,600 (5%)		F	
		Intercropping and two yrs. food, payed labor	Tsh 21,900 (5%)		F	
34	Mali	Community Woodlots	- 147,333MF (20%)		F	Wood valued at labor saved, Includes land value, seasonal wage rates
			- 117,500MF (10%)		F	" " " "
			+ 183,444MG (10%)		F	Cash sales of fruit
			- 183,444MF (10%)		F	Includes technical assistance and institutional support without environmental benefits
			0 (10%)		E	Environmental benefits of 12¢/yr/tree

con't. Profitability of Agroforestry Projects--Region: Africa

Reference	Country	Project Name and Description	PNW (r) (per hectare)	IRR(%)	Type of Analysis	Notes
34	Mali	Interplanting on Private Lands (hypothetical)	8,082MF (20%)		F	Includes environmental benefits
			26,856MF (10%)		F	Includes environmental benefits
			1,191MF (20%)		F	No environmental benefits
			28,000MF (10%)		E	Institutional support included
23	Nigeria*	Ex Post, Ibaelan fuelwood plantation (1966)		~2.5%	F	No land charge, no environmental benefits
21	Africa	Atriplex plantations		6.4-33.8	F	
		Acacia cyanaphylla plantation		0.1-27.0	F	Includes land opportunity cost
		Phyllodineous acacia plantation		7.3-28.9	F	
		Acacia senegal plantation		4.1-13.2	F	Gum arabic, wood and browse
		Acacia albida (taungya type)		8.2-19.9	F	
		Prosopis spp.		9.6-20.9	F	

con't. Profitability of Agroforestry Projects--Region: Asia

Reference	Country	Project Name and Description	PNW (r) (per hectare)	IRR(%)	Type of Analysis	Notes
29	Philippines	Albizia Falcataria pulpwood (1987)	₱ 1,579 (12%)		F	Based on data given in reference
10	Philippines	Philippine Smallholder Tree Farming (1979)	₱ 1,321 (12%)	39	F	
			₱ 1,283 (12%)	32	E	
10	Korea	Village fuelwood plantations	W 102.9 (12%)	17	E	Fuelwood valued in terms of coal & residues
35	India*	Farm Forestry, Vatava, Ahmedabad, Gujarat	Rs 68,811 (12%)	78.5	F	Irrigated Eucalyptus
	*	Sughad Village, private farm	Rs 11,123 (12%)	71	F	Irrigated Eucalyptus
	*	Lodra Village, private farm	Rs 9,567 (12%)	75	F	Irrigated Eucalyptus with intercropping
	*	Roadside plantations: Haryara State Railway Line	Rs 1,515 (12%)	32	F	Firewood & pulpwood, fencing & watering Rotation: 9 yrs.
	*	Haryara State G.T. Road	Rs 895 (12%)	16.5	F	Firewood & pulpwood, fencing, & watering Rotation: 13 yrs.
	*	Haryara State G.T. Road	Rs 423 (12%)	14	F	Firewood & pulpwood, fencing, & watering Rotation: 13 yrs.
	*	Gujarat: Palamjour-Deesa Road	Rs 250 (12%)	13	F	Neen and other species, fruit trees Rotation: 15 yrs.
	*	Gujarat (Northern Dist.)	Rs 1,874 (12%)	18	F	Neen & Eucalypt. Revenue from grass included Rotation: 30 yrs.
	*	Gujarat (Southern Dist.)	Rs 805 (12%)	13	F	Neen & Eucalypt. Revneue from grass included Rotation: 30 yrs.
	*	Village plantations: Gujarat: Pilvai Village	Rs 1,141 (12%)	20	F	Eucalyptus hy, Casuarina, fruit species, Rotation: 30 yrs.
	*	Gujarat Karpur, Forest Dept.	Rs 644 (12%)	15	F	Sissoo, mulberry, eucalyptus Rotation: 10 yrs.
	*	Gujarat Sujanipur	Rs - 145 (12%)	7	F	Prosopis Juliflora, saline soil Rotation: 15 yrs.
	*	Gujarat Mahisan	Rs - 701 (12%)	7	F	Accaria Nilotia cattle proof trench Rotation: 30 yrs.
	*	Gujarat Fulgram	Rs - 282 (12%)	10	F	Accaria Nilotica
	*	Haryana: Birbani	Rs 2,342 (12%)	29	F	Fuel, pulpwood, construction timber Rotation: 12 yrs.

con't. Profitability of Agroforestry Projects--Region: Asia

Reference	Country	Project Name and Description	PNW (r) (per hectare)	IRR(%)	Type of Analysis	Notes
35	India*	Village plantations: Haryana: Manakpur	Rs 1,121 (12%)	23	F	Fuel, pulpwood, construction timber Rotation: 14 yrs.
	*	Haryana: Kalanaour	Rs 512 (12%)	23	F	Fuel, pulpwood, construction timber Rotation: 1[illegible] yrs.
41	Nepal	Hill Village Forest Establishment		13.5	E	Fuelwood valued at dung equivalent, fodder ≈ incremental milk
		Fast growing fuelwood plantations		18	E	
		Fast growing fuelwood plantations w/Taungya		22	E	
		Agricultural settlement		47	E	No forest production
4	India	Madhya Pradesh Model 1	Rs 5,378 (10%)	22	E	Each model is a different mix of fuel, timber, fodder, fruit production; basis for output valuation not given
		Model 2	Rs 8,249 (10%)	24	E	
		Model 3	Rs 4,860 (10%)	20	E	
		Model 4	Rs 4,438 (10%)	19	E	

NOTES: Reference numbers refer to sources in reference section.

* = Ex Post Appraisals.

TABLE 5

INTERNAL RATES OF RETURN TO AGROFORESTRY PROJECTS

Average *Ex Ante* Returns

Region	# of studies	$\overline{IRR}$
Asia	10	22.7
Africa	15	9.5
Worldwide	25	14.8

Average *Ex Post* Returns

Region	# of studies	$\overline{IRR}$
Asia	17	27.4
Africa	1	2.5
Worldwide	18	25.9

Combined *Ex Ante* and *Ex Post*

Region	# of studies	$\overline{IRR}$
Asia	27	25.6
Africa	16	9.1
Worldwide	43	19.5

Obviously the determination of these projects' desirability depends critically on the selection of discount rate. In terms of the interest rates applied by project analysts themselves, roughly 75 percent of the projects reviewed are considered desirable as shown by a positive present net worth.

It is important to note that the results cited frequently depend on generous assumptions. To the extent that these assumptions are overly optimistic, projected rates of return should be revised downward. To the extent that nonwood values have been excluded, the IRR's should be adjusted upward.

C. Sources of Profitability

While it is difficult to attribute these results with certainty, several factors appear to be responsible for both the absolute profitability of individual projects and the relative advantage of projects in Asia. A major consideration is the existence of established markets for product output. Of the projects in both regions, those producing output for established cash markets (pulpwood in Nigeria or the Philippines, or commercial fuelwood as in India) appears more desirable. This probably reflects two issues, one being methodological: the quality of shadow price estimates for nonmarket values of wood and nonwood products; the other, the difficulty that managed stands have in competing with underpriced stumpage available from natural stands.

Another factor that contributes to the apparent superiority of Asian agroforestry is the, perhaps disproportionate, representation of projects in physical climates conducive to tree growth. For example, high growth rates are key to the profitability of the Philippines Small-holder Tree Farming project. Similar climatic conditions also contribute to certain agroforestry schemes in Africa (such as Taungya in southern Nigeria) but on a regional basis are negated by projects in arid areas such as the Sahel. Projects in dry areas of Asia, such as several projects in India, are far more likely to benefit from irrigation than any in Africa.

An additional advantage that many Asian countries possess is institutions with greater experience in forest management. This experience reflects itself in more desirable projects and less tentative project plans. Tree species and sources of planting stock are generally better known, lessening needs for species trials and increasing yield by allowing better matching of species with environmental conditions. Where a tradition of institutional experience is present in Africa, such as the Taungya plantations of southern Nigeria, profitable projects are clearly possible.

Policy constraints, such as unrealistically high wage rates in Kenya (Openshaw, 1980) or restrictions as to departmental or traditional Taungya schemes (Ball and Umeh, 1980 or R.G. Lowe, n.d.), may also affect profitability of agroforestry.

Interestingly, issues such as these arise in the literature with respect to Africa and not Asia.

There are no clear distinctions among the profitability of various types of agroforestry projects. Taungya plantations by virtue of generating early positive cash flow are generally more profitable than similar plantations without agricultural crops. Shelterbelts, when evaluated on the basis of wood values only, are seldom profitable. This in large part arises from high fencing costs per unit area and per unit of output. When crop protection benefits are considered, shelterbelts are judged profitable -- even more so when interplanting is possible at the time of establishment.

Although it is necessary to be especially cautious in drawing conclusions from studies done before projects are initiated, these general observations are reinforced by focusing specifically on the few ex post evaluations that are available. For example, it is clear that the principal difficulty faced by the Ibadan Fuelwood Plantation was low-cost wood from natural stands and the cheap commercial fuels that were available over the life of the project and at the time of the study (King, 1966). Similarly, several of the projects reported on by Srivastava and Pant (1979) were clearly producing fuelwood for commercial use by railroads and institutions. In addition, the three most profitable Indian projects were irrigated plantations.

D. Methodological Issues

Aside from these observations with respect to profitability, a number of methodological issues were raised in the review of the available benefit-cost literature. General issues and examples of literature will be presented, followed by a discussion in more detail on the specific approaches. While most studies employ a conventional discounted cash flow approach, five basic issues remain. These are: the choices of discount rate; the specification of the appropriate with/without choice; the choice and implications of accounting perspective; the implications of both technical and economic assumptions; and the treatment of nonwood values.

1.) Discount rate. -- The choice of discount rate is a perennial problem in the analysis of investment projects, and agroforestry is clearly no exception. Close examination of Table 4 reveals several examples where small changes in the choice of discount rate can result in changing the accept-reject conclusions of the analysis. Other than indicating the significance of the discount rate and the usefulness of calculating the IRR as a sensitivity test, no concrete conclusions can be reached regarding the appropriate discount rate.

One interesting example of the discount rate's effect on choice of projects is given by Hosier and Gelder (1982). They analyzed a hypothetical choice between a

conventional eucalyptus woodlot and an alternative "fuelstick" scheme (tightly spaced, short rotation, fast-growing Calliandra calothyrus plantation). By varying discount ratesfor each project they found the IRR's for each and the discount rate at which the PNW of the two are equal. This is shown in Figure 5. The IRR for the fuelstick project is 250 percent, far higher than for the eucalyptus woodlot (IRR = 49 percent). However, in the range of discount rates likely to be relevant, the PNW of the two projects are very close and equal to each other when r = 5 percent. If the actual discount rate is below 5 percent, then the conventional project is preferred to the fuelstick scheme. In addition, if other features of the project analyses are uncertain then the choice is not nearly as clear as is suggested by the IRR's.

2.) With/without choice. — One difficulty in interpreting the results of much of the agroforestry benefit-cost literature is the identification of the relevant with/without choice. Essentially this is a problem of assigning the correct opportunity cost to land. This arises from several aspects of the nature of agroforestry projects, the most important being the joint product character of most projects. Additional issues are lack of data, the difficulty of forecasting without project trends and, related to the joint product aspect, the multiplicity of possible alternative project designs.

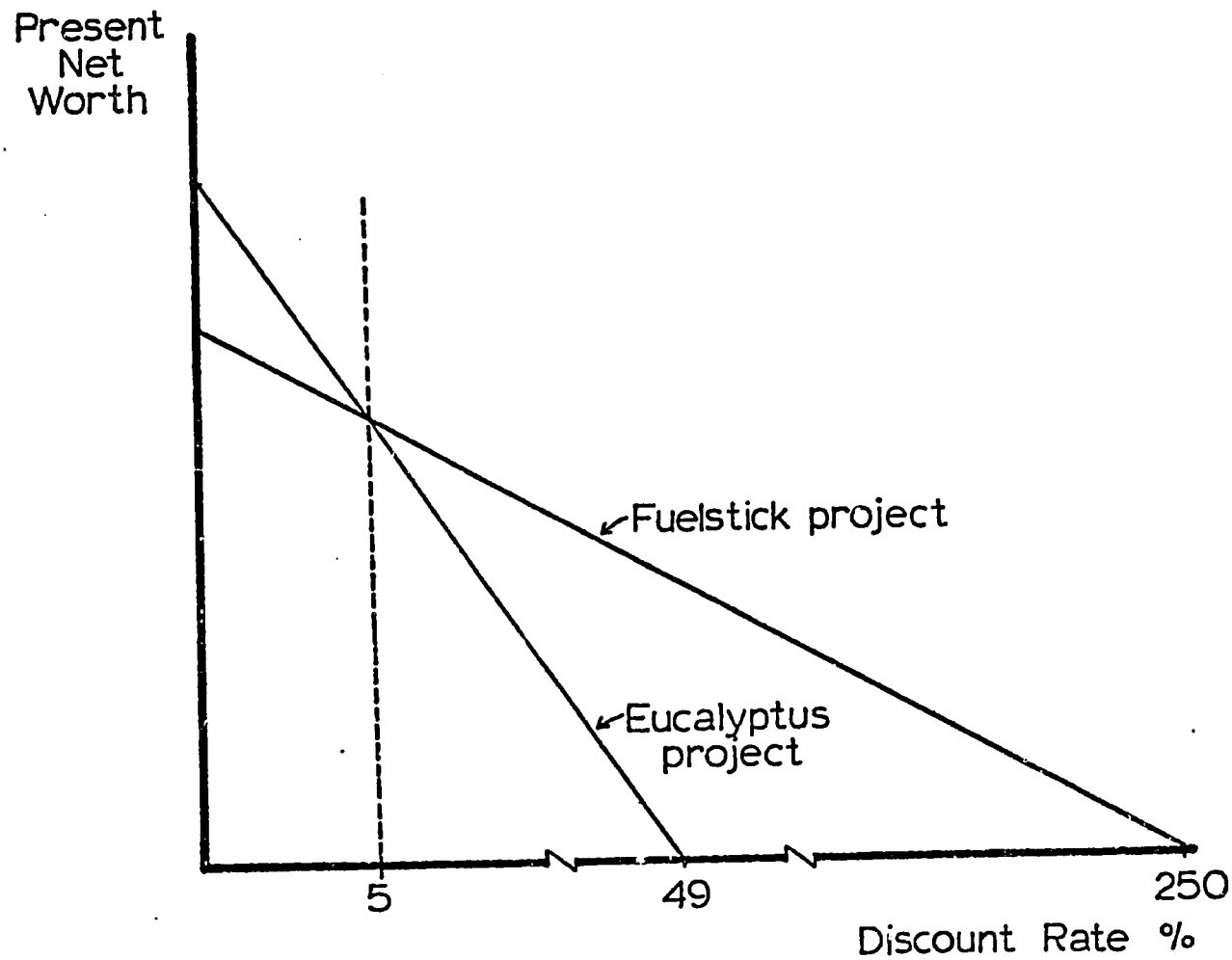
Underlying discounted cash flow analysis of projects is the notion that a choice exists between alternative future outcomes contingent upon the acceptance or rejection of a particular project. The analysis of proposed projects is intended to determine which decision leads to the most desirable outcome. Normally, projects can be evaluated independently according to a with/without analysis. In the case of agroforestry because a given unit of land can normally be used for only one activity or one set of activities, it is necessary to consider mutually exclusive projects. One way of dealing with this is to charge all alternatives a land price at the beginning of the project, or an annual land rent. Many benefit-cost evaluations in the literature do neither.

Hofstad (1978) considers five alternative forestry or Taungya projects in Tanzania:

i) Wood production alone;
ii) Two years of intercropping of trees and food crops followed by the balance of a 24-year rotation;
iii) Three years of food crops, followed by 2 years of intercropping followed by the remainder of a 24-year rotation;
iv) Five years of food crops, followed by 3 years of intercropping followed by the balance of a 24-year rotation;

FIGURE . 5

_..._t of Discount Rate on Present Net Worth
of Alternative Forestry Projects in Kenya



SOURCE: Based on Richard Hosier and Berry Van Gelder, "The Economics of Optimal Fuelwood Production Techniques," Beijer Institute Fuelwood Project Working Paper, March 1982.

v) Intercropping of trees and crops for 2 years followed by 22 years of trees alone employing wage labor rather than allowing subsistence cultivation.

Per hectare present new worth (PNW) for each of the options (at 5 percent discount rate) are summarized below:

TABLE 6

PRESENT NET WORTH FOR 5 PROJECT DESIGNS
(Tanzanian Shillings/ha)

Option	1	2	3	4	5
PNW	13,200	25,600	36,400	47,600	21,900

Clearly any of the five project designs are acceptable; however, since only one of the options can be implemented on any given piece of land, the most desirable choice is the fourth option. It is necessary to point out, however, that the basic choice(s) is(are) not clear. For example, if the choice is either wood production alone (option 1) or any one of the other four options, there is in reality a choice among four alternatives. Similarly, if there are other options, ie., of sustained agricultural production or doing nothing, there are in fact five or more alternatives. If sustained agriculture without trees is in fact possible, it would be necessary to charge a land cost against the various options.

Presumably in this case, sustained agricultural production is not possible, although it is evidently possible for at least five years. It is conceivable that crop yields would decline after five years beyond a profitable level or that irreversible soil damage would occur. It is also conceivable that nonforestry options, such as terracing or contour plowing could extend the cropping life of the site. Most likely, sufficiently detailed information is not available in order to enumerate all possible options much less to make a quantitative analysis of them.

An example of the significance of considering all relevant alternatives is provided by preliminary analyses done by a World Bank mission to Nepal in 1978. The analysis compared three alternative land uses: i) fast-growing fuelwood plantation; ii) fast-growing fuelwood plantations with food intercropping during the first two years, and; iii) traditional agricultural settlement. The results of the analysis, summarized in Table 7 below, clearly favored traditional agricultural settlement. Based on these results the conclusion was reached that wood production should be limited to land unsuitable for crop production, for which the appropriate annual rent charge would be zero.

3.) Accounting perspective. -- Another difficulty in interpreting the analyses of projects is the frequent blurring of the distinction between accounting perspectives. There are usually three vantage points from which agroforestry projects can be usefully appraised: i) the individual operator, the farmer or forest manager; ii) the forest development agency; and iii) the economy at large. When, as is frequently the case, costs and benefits to the various factors differ it is most desirable to have separate analyses. In this way the likelihood of determining if projects are both self-sustaining and socially desirable is enhanced. If a socially desirable project is found to be privately unprofitable then the need for, and feasibility of, subsidies can be assessed.

As indicated in Table 4 the most common accounting stance employed in the agroforestry literature is a private accounting or financial stance that utilizes unadjusted market prices. The most common deviation from conventional market prices is the use of some sort of shadow price for home consumption of fuelwood. Despite this general stance, attempts to include nonmarket benefits, particularly environmental ones but also domestic consumption, frequently credit projects for benefits even though they accrue to other entities.

An example of this difficulty is given by Nautiyal's (1979) appraisal of shelterbelts in northern Nigeria (this study will be reviewed in detail later). While the basic approach is sound, Nautiyal (in considering the value of shelterbelts established by the Nigerian Forestry Department) credits the project with crop protection benefits enjoyed by neighboring farmers. While from a global perspective these are certainly benefits, since they are not received directly by the Forestry Department nor is the Forestry Department compensated by farmers, they cannot be credited to the project in strict financial terms. In order for crop protection benefits to be legitimately considered, it would be necessary to adopt a broader accounting stance or to be reasonably able to expect a suitable system of side payments to be instituted.

Similar difficulties arise in the analysis of alternative arrangements of Taungya systems. One issue analyzed in several studies of Taungya systems, for example, is the use of hired labor or "contracted" subsistence cultivators (see Ball and Umeh, Lowe, and Hofstad). From the perspective of the executing agency, cash wage payments or payments in kind are appropriately deducted as costs of the project, similarly benefits are the value of harvest net of workers' consumption.

However, a broader issue that has not been studied is whether net economic benefits are affected by the institutional arrangement of Taungya systems. When an accounting stance is employed that encompasses both peasant cultivators and forest

TABLE 7

PROFITABILITY OF ALTERNATIVE LAND USES IN NEPAL

Alternative	IRR	Value of Average Annual Production Rs/ha/yr	Net Present Value of Average Annuel Production[1] Rs/ha/yr	Employment Man Days/ha/yr
1	18	1,160	140	16
2	22	1,200	175	17
3	47	2,700	435	166

[1]At 10% discount rate.

SOURCE: World Bank, 1978.

authority; wage payments and consumption of harvest are mere transfers of resources. The question then becomes is the overall net benefit from the project greater under one system or the other. Higher net benefits could occur, if cultivators who rent land exercise greater care and produce higher yields than laborers who are simply hired and supervised by forest managers.

4.) Assumptions. -- Underlying almost all ex ante benefit-cost analyses of agroforestry appears to be a tendency to make favorable assumptions, especially about project performance, that critically affect the results of the analysis and that appear unfounded based on ex post evaluations of other projects.

For example, seedling survival rates play a major role in determining the ultimate profitability of forestry projects and are often used as partial indicators of project success. The appraisal report of the Upper Volta Koudougou Agricultural Development Project (Winterbottom, 1979) lists survival rates from previous projects as below 50 percent for the first years. While a formal benefit-cost analysis is not presented, yield estimates for future plantations are based on 90 percent survival. Although changes in management and administration are prescribed, 90 percent seems overly optimistic. An appropriate approach would be to use survival rate in sensitivity analysis.

Another example of the use of optimistic assumption in the analysis is given by Openshaw's (1980) estimates of fuelwood production in Kenya. Noting that wage rates for forestry work appear unrealistically high in Kenya (when compared with neighboring Tanzania and even some developed countries), Openshaw conducts his analysis using deflated figures. These levels are said to represent reductions that could be achieved through improved management and policy changes. The feasibility or likelihood of these changes, however, is not addressed. Here again, the appropriate approach is to use a broader accounting stance that covers the entire economy. Then, if the high wage rates do not reflect actual social costs, it is appropriate to consider extra normal wage payments as transfers. Nonetheless there remains the question of how a program can be made self-sustaining if the agency responsible for its implementation is expected to incur continuing loses.

5.) Nonwood values. -- Although nonwood values are one of the key justifications for recent emphasis on agroforestry, with the exception of agricultural crops, they receive essentially no attention in economic analysis. Sheikh and Larson, Openshaw, Hofstad and others include in their analyses values for food crop output, minor products such as honey and fruit, and fodder. The most detailed attempt to include nonwood values, principally browse, is found in ILCA (1980). While, in some cases, different values could be proposed for subsistence consumption, generally their

approaches are appropriate. On the other hand, almost no attempt has been made to evaluate environmental benefits such as crop and soil protection, erosion control, or amenity values. One exception to this is Nautiyal's study of shelterbelts.

In the following section examples are given of ways in which nonpriced values, including domestic wood consumption and environmental benefits, can be included in project analysis.

METHODOLOGICAL ISSUES OF AGROFORESTRY PROJECT APPRAISAL

INTRODUCTION

As shown in the previous section the traditional common property nature of forest resources has led to a situation in which desperately poor people are led to dissolve, at a faster than desirable rate, their stock of forest capital. The consequences of this increased time and effort of collection are environmental degradation. Attempts to influence these trends include physical investment projects and the development of more efficient and equitable institutions. In this sense projects are some form of investment activity in which resources are expended in order to create a productive asset from which future benefits are expected. Appraising these efforts from an economic perspective is an important component of policy formulation. As indicated, there are theoretical and practical issues in project evaluation that have major implications for project selection but which have received inadequate attention.

The basic approach of benefit-cost analysis is well developed (UNIDO, 1972, Little and Mirrilees), and will not be the primary focus here. This section will deal with approaches to valuing nonmarket inputs and outputs. The particular areas to be addressed include externalities that may not be readily measured even in physical terms, shadow pricing of fuelwood, and specific inclusion of merit wants such as of reducing women's labor and generating nonfarm employment.

Fundamentally there is little difference between the appraisal of agroforestry and more conventional projects. The differences that do exist are the extent to which nonmarket values are relevant and the need to incorporate them into the analysis. In most instances satisfactory methods for this have been proposed and the problem is often one of selecting the appropriate method(s). Often shadow pricing of these aspects requires technical or economic information that may be unavailable or unobtainable at reasonable cost or within the cosntraints of time. In some circumstances there may be alternative shadow pricing techniques which yield

different values and imply different courses of action. In this section a number of approaches to dealing with unpriced values in agroforestry are reviewed and discussed. There are three basic ways of dealing with these concerns. When there is a lack of information, is it appropriate to determine the minimum value necessary for difficult-to-value components in order to make an overall project desirable? In the case of alternative approaches, such as different ways of shadow pricing fuelwood, the problem can be approached in terms of opportunity cost, specifically asking how does the output (input) relate to the constraints on or objectives of the target group. Finally, there is always the opportunity to collect more accurate or structured information on which to base shadow prices.

EXTERNALITIES AND ENVIRONMENTAL BENEFITS

Forest plantations are known to provide environmental benefits as previously discussed. They may or may not be appropriated by individuals, thus environmental benefits may be relevant for financial analysis but should certainly be considered in economic and social analysis. Environmental benefits tend to be diffuse, difficult to measure physically, and dependent on a number of factors. Shelterbelts provide an example of reasonably easily measured environmental benefits from agroforestry. In addition to standing timber (which, depending on management, may have value in itself), shelterbelts provide protection to crops from wind-blow, improve conditions for evapo-transpiration, and reduce soil erosion. These can be individually measured using standard techniques or their combined result can be measured in terms of incremental crop yield (for examples of techniques and yield measurements see literature cited in Magrath, 1979). Similarly soil erosion and run-off from forested and deforested slopes can be measured and compared (see Kunkle, 1978). While these and other outputs from forests can be measured, the research is expensive, time-consuming and skill-intensive. Moreover, benefits may vary over time requiring prolonged monitoring. For example, the yield effects of shelterbelts is partly a function of height and age, and also depends on the severity of weather in a particular year.

Presuming that the physical effects of trees are in fact known, expressing them in value terms may be difficult. In the case of shelterbelts, for example, if yield increment is known the benefit is simply the quantity of the increment times unit price. However if the effects are only expressed in terms of reduced wind velocity or water balance changes no direct valuation is possible. An indirect approach would need to be based on some technical hypothesis relating these changes to crop yields and hence to monetary benefits. Similarly, reduced erosion from steep hillsides needs

to be valued in terms of the future production made possible by soil stability and/or reduced maintenance costs in downstream irrigation facilities, etc. Volume of soil-loss prevented is necessary but not sufficient datum for such a calculation. Two approaches to these valuation problems are given below.

A. Estimating Values for Environmental Benefits Based on Technical Information

An approach to benefit-cost analysis when there are external benefits that are difficult to value is illustrated by Nautiyal's (1979) evaluation of shelterbelts in Nigeria. The technique is to develop a technological hypothesis that relates the project to physical, i.e. quanitative, changes in a readily valued output. The value of that incremental output then simply becomes an additional benefit credited to the project. Obviously, if it is clear that the project is desirable even if environmental benefits are zero, it is only necessary to ensure that they are in fact positive and the project can be accepted without further investigation.

Nautiyal's investigation concerned the profitability of shelterbelts in Katsina, Sokoto, Kaduna, Kano, and Borno States, Nigeria in 1978. This study was mentioned previously, with respect to the specification of accounting perspective. Here this subtlety is ignored. Using data on plantation establishment, maintenance, and harvesting costs, he estimated the present value of all costs for 52 years (at 6 percent discount rate), except land, to be ₦180.31 per hectare (ha) of windbreak. Managed on a sustained basis during this time the belt would yield ₦612.89 of (present valued) timber and fuelwood. The present value of food crop production foregone would be ₦246.67 per ha of land occupied by the belt. An administratively set land price, however, would require the Forestry Department to pay ₦518.9 per ha. Assuming all costs included in the ₦180.31 per ha to represent true social costs, financial and economic analysis compare as follows:

TABLE 8

	Financial	Economic
Establishment and Maintenance Cost (Discounted)	₦ 180.31 /ha	180.31 /ha
Land	518.90 /ha (administratively determined)	246.67 /ha (opportunity cost)
Present Value of Costs	699.21 /ha	426.98 /ha
Present Value of Revenues	612.89 /ha	612.89 /ha
PNW (without crop protection)	- ₦ 86.32 /ha	₦ 185.91 /ha

Even without accounting for benefits from crop protection, shelterbelts were shown to be desirable from an economic point of view. From a financial point of view they are unprofitable. However, this unprofitability is in part a consequence of neglecting the environmental benefits of shelter.

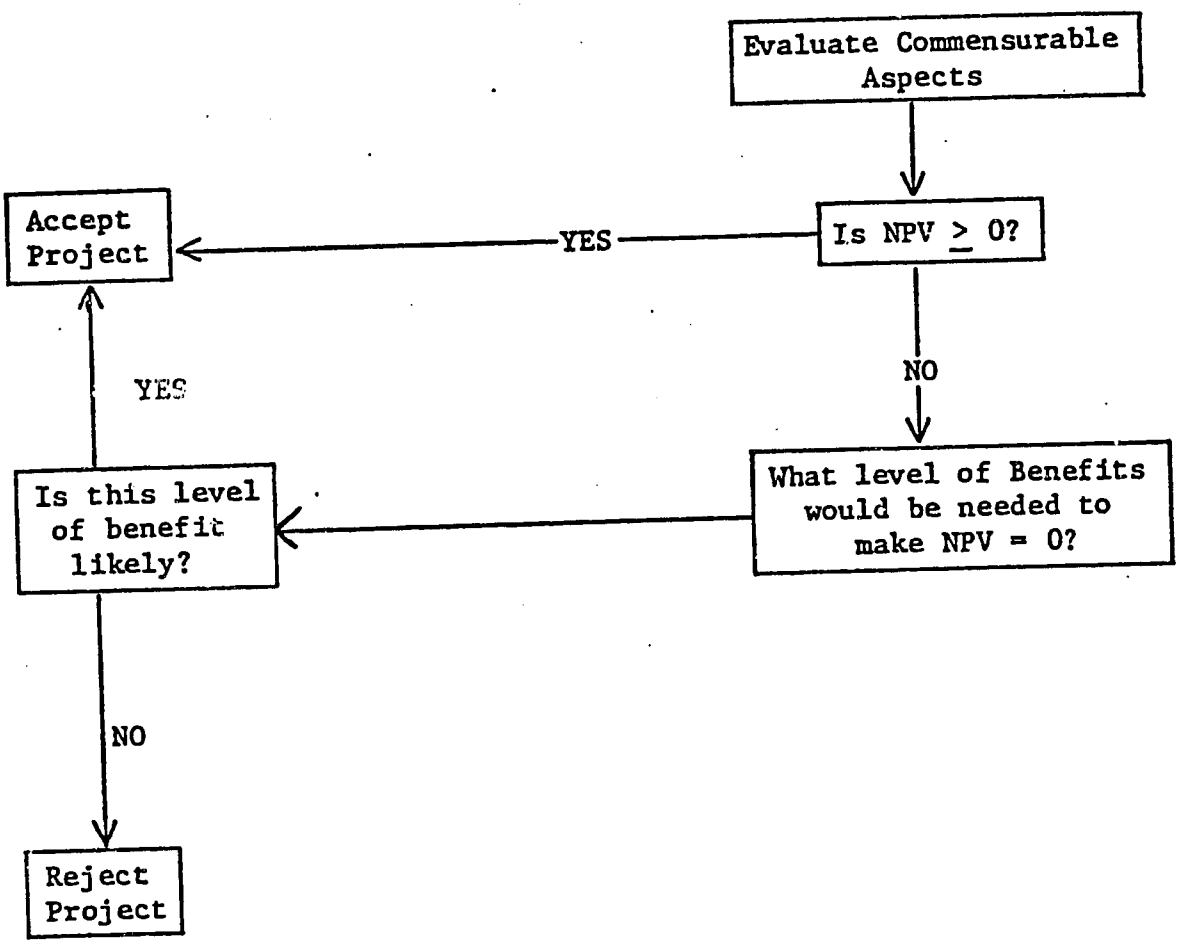
Nautiyal, based on a review of the literature on shelterbelts and discussions with local farmers, concluded that a conservative estimate of the yield increments made possible by shelter would be 10 percent per annum starting after the fifth year. Even when based on low-profit crop combinations, the present value of incremental crop production would be ₦251.71. Added to the negative financial PNW in Table 8, the overall value is positive ₦165.39 ha of windbreak assuming that the forest service would capture these benefits. If added to the economic evaluation, the total PNW is ₦437.62. If less conservative assumptions are made concerning farmers' selection of crop mixes, both economic and financial profits are substantially higher. This analysis led Nautiyal to strongly recommend extended establishment of shelterbelts.

B. Estimating Switching Values for Environmental Benefits

The valuation problem can also be approached in a slightly different manner, that may be more useful for difficult-to-value benefits. The term "switching value" refers to that level of benefit where the accept/reject conclusion of the analysis changes or switches. For example, in the shelterbelt project described above, given that the project will last 52 years and that benefits of shelter will start in the sixth year, the analyst could ask: what would be the necessary level of physical benefits to cover the projected financial loss of ₦86.32 ha of windbreak? The present value of ₦1 received annually between 5 and 52 years inclusive, at six percent, is about ₦11.6. Therefore, in order to cover a (present valued) ₦86.32 loss, an annual increase in net return from crops of ₦7.5 would be necessary. Since one hectare of plantation provides protection to 13.83 ha of farmland, this is equivalent to an increase of ₦.54 per ha. With current net farming revenue per ha at ₦16.5 this is a 3 percent increase (a 3 percent increase in net revenue probably does not require a full 3 percent increase in yield because costs do not change in proportion to revenues). Nevertheless, it is clear that if even a 3 percent yield increase could be expected, the shelterbelt is justified. Given Nautiyal's field observations and his literature review, a 3 percent increase is well within the realm of possibility. Figure 6 summarizes this approach to dealing with positive benefits.

FIGURE 6

SWITCHING VALUE APPROACH TO APPRAISAL OF PROJECTS WITH POSITIVE, BUT INCOMMENSURABLE BENEFITS



SHADOW PRICES OF DOMESTIC CONSUMPTION

As was discussed previously, food, fuelwood and other agroforestry products are frequently consumed by the same household that produces or collects them. When projects are proposed that will, for example, replace wood from the forest with wood from managed stands, the analyst is faced with the task of inputing unit values for wood. A variety of approaches have been proposed and used in project appraisals, and it is frequently asked which approach is correct. In general there is no single correct technique. The view proposed here builds upon the role of wood in adding to the welfare of rural families that was described above. There it was emphasized that rural families are limited in their production and consumption choices by a variety of constraints. Forest products are both consumer goods and producer goods for the rural family serving as end-use needs (fuel) and as inputs to other production processes (implements). Given this, additional wood can be valued, based on how it directly contributes to consumption or contributes indirectly by easing constraints on the productive resources of the family.

For example, if firewood is currently gathered at great distances from the homestead and the labor requirement interferes with other productive activities, it is correct to value wood based on the foregone product of labor. It is then necessary to impute or observe relevant wage rates for women, children, peak and off-peak season, as the case may be. If additional firewood will replace cattle dung, in an area with heavy pressure on land resources, then it is appropriate to base the valuation of wood on the marginal productivity of cattle dung in food crop production. It is conceivable that additional supplies of wood will contribute in more than one way to the welfare of rural families. When this is the case it is appropriate to take all these contributions into account in valuing wood. Shadow prices for nonmarket products could be based on a systems analysis approach. Such an approach would seek to incorporate all the costs and benefits of expanded wood production based on an objective function thought to represent the utilityfunction of rural families. It would incorporate production relationships, could include risks and the complementarity and competitiveness of alternative activities. Such a general approach has not been used in project analysis to date. Instead, one much more relevant to practical project appraisal, partial approaches that focus on particular trade-offs have been employed. These approaches which require much less data and less observation of small farm decision making will be examined here.

The techniques for application of these approaches are straightforward and based on opportunity cost considerations. In actual practice though a number of important

subtleties, technical and economic, need to be borne in mind. The rest of this discussion will address these issues in the context of five representative approaches that have been used or proposed for shadow pricing fuelwoods. These deal with: i) time spent collecting; ii) cost of production; iii) dung residue replacement; iv) commercial fuel replacement; and v) market prices. The common feature of all these appraoches is that they involve assumptions about the substitutability of project wood for other fuels. Needless to say the appropriateness of these assumptions is a critical issue in the application of any of these methods.

While in most project evaluation situations availability of time and data will only allow calculation of one or perhaps two alternatives shadow prices it would be desirable to calculate as many as possible using different approaches. All approaches presume that an opportunity cost is incurred by the family when it devotes resources to energy consumption, either in terms of labor, cash, or agricultural output. In theory a maximizing household will allocate its resources in such a way as to equate costs at the margin. Thus, if resources are substitutable, the opportunity cost of wood as calculated by any of the approaches should be equal. If not, as will frequently be the case, review of the assumptions and criticism of the various techniques will help to indicate the appropriate choice for a particular situation.

A. Market Prices

When available, actual market prices are an appropriate place to start in valuing firewood. Clearly, when wood is to be grown for sale, market prices or expected market prices are the correct value for financial project appraisal. Often projects promote family or communal wood production aimed at displacing wood from natural stands or agricultural residues. Market prices may still be relevant, given that a number of conditions are met.

Most important is that existing markets are available to potential project beneficiaries. In so long as markets are open to these people it can be presumed that they can efficiently compare their subjective valuation of wood with existing market prices (net at transportation costs). Therefore, even if they choose not to participate in market transactions, the meaning of the market price is not compromised. One aspect of market availability is spatial: are markets located in reasonable enough proximity to allow beneficiaries to enter as buyers and sellers? Other aspects are: are there barriers to entry, monopoly or monopsony power, or price discrimination that effectively prevent markets from being available? Moreover, the common property availability of natural forests may hinder the social efficiency of rural people's supply response to wood prices.

Based on the available literature it appears that these conditions are seldom met sufficiently well enough to justify the use of market prices in financial analysis from the perspective of small farmers, or from broader economic or social perspectives. Generally only a small portion of firewood consumed in developing countries goes through a functioning market. The distance between wood supplies and markets frequently give special advantages to firms with access to trucks and working capital. Finally administratively established stumpage prices (which are frequently unreasonably low) may dominate the determination of market prices. LDC stumpage prices are often set by government fiat and may bear no relation to actual social costs of regeneration. Unregulated and illegal harvests from natural stands also frequently occur with little or no threat of effective enforcement.

To some extent, market imperfections can be identified and quantified using conventional economic analysis to allow estimation of correct prices. This approach does not seem to have been attempted in the forest products sector of any developing country.

Although market prices may be considered faulty, they can not be totally dismissed in project design. To the extent that there is a difference between market prices and the value of project wood, incentives may be introduced that will distort project objectives. For example, if production from a project is priced higher than existing market supplies, there may be difficulties in marketing. If new output is cheaper than existing supplies, there may be incentive for beneficiaries to resell output at something close to market rates. The high transport cost of wood may mitigate these potential problems.

B. Commercial Fuel Replacement

The term "the other energy crisis" implies a coincidence between the decreasing availability of firewood in developing countries and the dislocations that have accompanied the end of cheap energy in the industrialized world. It seems natural for some purposes to base the valuation of firewood prices on the caloric equivalent of commercial energy sources. Given a market price for the commerical fuel, which is by definition known, and the energy values of wood and the alternative, the calculation of a shadow fuelwood price is easily done. A hypothetical example of this calculation is described below, from Gregersen and Contreras (FAO, 1979).

Suppose the output of a project will be fuelwood that will replace the currently used fuel, kerosene. Caloric values for wood and kerosene are 188,000 Kcal/m^3 and 3200 Kcal/liter. The price of kerosene, adjusted for transport and the shadow exchange rate, is $0.40/liter. In order to establish the equivalent price for wood equation (1) is solved.

$$(1) \quad \frac{\text{Price (wood/m}^3)}{\text{Kcal/m}^3} = \frac{\text{Price (kerosene)/liter}}{\text{Kcal/liter}}$$

Substituting the values given and solving:

$$(1') \quad \frac{\text{Price (wood)}}{188{,}000 \text{ Kcal/m}^3} = \frac{\$0.40/\text{liter}}{3200 \text{ Kcal/liter}}$$

$$(2) \quad \frac{\text{Price (wood)}}{188{,}000 \text{ Kcal/m}^3} = \$.000125/\text{Kcal}$$

$$(3) \quad \text{Price (wood)} = \$23.5/\text{m}^3$$

While intuitively appealing, this calculation implies a number of assumptions which the analyst may be unwilling to make, and which should at least be made explicit. These are both technical and economic in nature.

The technical issues are most easily dealt with in careful appraisal work. For example, the use of the analysis must be careful to use net rather than gross caloric values. It is now widely accepted that traditional stoves and kilns usefully employ only a small fraction of the gross wood energy available. While the concept of energy efficiency in stoves is difficult to quantify, estimates of efficiency range to below 5-10 percent.

Draper (1977), in the appraisal of a rural development project in Tanzania, has developed an analysis of effective cost per unit of energy (see Table 9) which illustrates the impact of differential efficiencies. Various fuels are burned with different levels of efficiency, hence these are different effective energy values per unit. Consequently, price comparisons using net and gross bases can yield considerably different results.

Even when efficiency of use is taken into consideration, the correct choice of units and caloric values for wood itself are important considerations that receive inadequate attention. Oven-dry wood, of essentially all species, on a weight basis is of very consistent energy content. Table 10 gives oven-dry caloric values for several important tropical fuelwoods. Note the similar calorific values on a weight basis, however the differing densities give rise to substantial differences in energy value per unit volume. Normally, wood is burned air dry, or at 25-30 percent moisture content. To further complicate matters, wood is traditionally measured in volume units which may be "solid" or "stacked." For example, a solid cubic meter of air-dry wood will weigh on the order of 720Kg while a stere or stack cubic meter, might weigh only 480 kg.

TABLE 9

CHARACTERISTICS AND PRODUCTIVITY OF SELECTED FUELS

Type of Fuel	Average Gross Calorific Value (Thousand Kilo-calories per Kilogram)	Approximate Household Efficiency (%)	Effective Kilocalories per Kilogram	Effective Kilo-calories per Unit
Air-dry Wood	3.5	7.5	0.26	188/m^3
Charcoal	7.1	27.5	1.95	1,950/ton
Kerosene	10.4	37.5	3.90	3.2/liter
Propane Gas	11.0	55.0	6.05	—

SOURCE: Draper, 1977.

TABLE 10

CALORIFIC VALUES FOR MAJOR FUELWOOD SPECIES

Species	Calories/gram	Specific Gravity (Density)	Calories/cm^3
Gmelina (*Gmelina arborea*)	4.850	0.46	2.230
Neem (*Azadirachta indica*)	4.780	0.75	3.585
Eucalypts:			
E. crebra	4.800	0.92	4.415
E. alba	4.730	0.74	3.500
E. camaldunensis	4.715	0.72	3.395
Cassia (*Cassia siamea*)	4.630	0.81	3.750

SOURCE: J. Doat, "Le Pouvoir Calorifique Des Bois Tropicaux," *Bois et Forêts des Tropiques*, no. 172, March-April 1977, pp. 33-55.

On a volume basis the energy content of wood varies widely among species depending on both moisture content and specific gravity (density).

While these technical aspects are easily dealt with (most easily by working on the basis of weight), a number of economic issues are less amenable to resolution. These relate principally to the substitutability of wood for other fuels. Table 11, again based on Draper, shows a substantial difference in price per effective kilocalorie (Kcal) for three fuels in Tanzania. Using the approach given in this section, the variation in price would not occur. Nonetheless, the variation may be completely reasonable. For example, transportation costs per kilogram for wood may be higher than for charcoal leading to a higher price, or kerosene may be purchased by more affluent consumers, or may simple be more highly valued than wood due to greater convenience. Of course it is possible that there are factors that distort market prices and that the correct price for wood is Tsh 99.*

It is also necessary to consider other parts of the implied shift from alternative fuels to wood. Consumers may be unwilling to abandon investments in gas stoves, for example, when wood prices are only just equal to gas prices.

As a final note, there are differences in the correct application of this shadow pricing technique that depend on accounting perspective. In the case of financial analysis, all other things equal, actual market prices for commercial fuels are an appropriate basis. In economic analysis, the commercial alternatives themselves should be appropriately shadow priced, especially in the case of imported fuels (see UNIDO, 1972). Finally, there may be other objectives, such as energy self-sufficiency or a preference for renewable energy sources that should be reflected in social analysis. In these cases, it may be appropriate to add a premium to the market price of the alternative to reflect these additional social or economic costs.

C. Dung/residue Replacement

Observations in many parts of the developing world that, in the face of wood scarcity, rural people resort to burning animal dung and crop residues have led to the suggestion that the fertilizer potential of these residues is an appropriate basis for wood pricing. The mechanics of this approach are similar to a commercial fuel equivalent approach. It also presents similar technical issues and comparable economic ones.

The approach is illustrated in the World Bank Forestry Sector Review of Nepal. The caloric value of air-dry wood was assumed to be 4.7 Kcal/ton compared to dried cattle dung with 4.0 Kcal/ton. Therefore, about 1.2 tons of dung would be saved for each ton of additional wood made available. Using a factor of 0.5 to convert tons of

*It is also possible that the 7.5% assumed efficiency is incorrect. This could lead to a misleading conclusion.

TABLE 11

COMPARATIVE COST OF TRADED FUELS
(Tanzania Shillings)

Type of Fuel	Market Price	Kilocalories per Unit*	Cost Per Kilocalorie
Air-dry Wood	$80/m^3$	188	0.426
Charcoal	500/ton	1,950	0.256
Kerosene	1.7/liter	3.2	0.531

NOTE: *See Table 9.

SOURCE: Draper, 1977.

wood to cubic meters, 0.6 tons of dung is the equivalent of 1 m^3 of wood. The ratio of dried cattle dung to farmyard manure is 1:4, therefore, the 0.6 tons of dry dung is the equivalent of 2.4 tons of fresh manure. One ton of manure is expected to raise maize output per hectare by 34 Kg, worth Rs 40 (at Rs 1,200/ton). Therefore 2.4 tons of manure or one ton of dry dung or one cubic meter of wood are all worth Rs 96.

Many of the same difficulties mentioned for commercial alternatives plague this approach to valuing wood. There is the same need to ensure that units of wood volume are used consistently and that comparable efficiencies are assumed (in the example above, it is assumed that wood and dung are burned with the same relative efficiency. Therefore, there is no need to convert to effective energy content as was done with commercial fuels). In addition it is necessary to have reliable information on the marginal productivity of dung as fertilizer. It is likely that marginal product varies and eventually falls so that if relatively large diversions are anticipated (in a sense, a nonmarginal project), it is necessary to have data that cover a range of levels of manure application.

In general it appears that values for energy content, especially of nonconventional fuels such as dung, have been taken at face value from available documentation. Consequently it is difficult to determine if the use of different values reflects particular features of different situations. As an example the World Bank study of Nepal assumed that dung has a coal replacement value of 0.4 (2.5 MT of dung supplies the energy equivalent of 1 MT of coal). Another World Bank document, the India Uttar Pradesh Social Forestry Project Staff Appraisal Report, citing a Government of India report, used a coal replacement value of 0.3 (3.3 MT of dung equal to one ton of coal). The reason for this differential is unclear, especially given that Uttar Pradesh borders on Nepal. As an indication of the significance of this discrepancy, the Uttar Pradesh report calculates the annual wood harvest that would be necessary to replace cattle dung for the state's population of 85 million as 9.4 million m^3. Using the Nepal value the wood requirement would have been calculated as 13.6 million m^3, a difference of 4.2 million m^3.

What is perhaps more significant (with respect to using food output foregone as a basis for firewood pricing) are the implied behaviorial assumptions. For example, the entire basis of this method is that the marginal product of an input will be set equal to its price. For a firm operating in long run equilibrium in a perfectly competitive market, this is a reasonable assumption. However, to the extent that farms are not being operated in a strict neoclassically efficient manner, the imputed price will be incorrect.

Similarly, it is also necessary to consider the possible impact of agricultural price policies on levels of input use. While the general approach of with/without analysis focuses only on changes related to the specific project under consideration, distortions that can be corrected by policy changes should be identified.

It is also assumed that wastes are considered inferior to wood as fuel, so that simply expanding wood supplies will decrease the use of dung. It has been suggested that to the extent that residues are readily available and convenient, rural people will continue to use them even with more abundant wood. For example, when crop residues like millet stalks are available in close proximity to the homestead following harvest, they may provide an acceptable fuel.

The calculation used above also makes no explicit consideration of any differences in labor requirements for collection and processing of dung or wood. Presumably the differences are thought to balance each other out. Alternatively, not including labor could imply a wage equal to zero (or a marginal product of labor equal to zero).

In fact, relative factor prices are the key in determining the relevance of this approach. Dung or other residues that have fertilizer as their principal use, can be thought of as potential increments to land. In a situation in which land is scarce and labor is applied intensively, the marginal productivity of land will be high and of labor low. Thus it would be appropriate to value wood on the basis of dung replacement.

On the whole, the use of fertilizer potential as a basis for wood pricing, is probably a reasonable approach in areas such as South Asia where demand for land is high. In areas, such as Subsahara Africa, where land availability is typically not a constraint, alternative approaches will be more desirable.

D. Cost of Production

While not actually an approach to valuing wood, the cost of production approach essentially asks: what price would be necessary to justify a project? The cost of production approach is implicitly based on the conversion returns method, familiar to foresters and the theory of derived demand, familiar to economists. It has been used in both project appraisal and sector analysis work.

In sector analysis the conversion returns approach is employed to trace, and attribute, the value added to stumpage as it is transformed from raw material to intermediate to finished product. The difference between the summed value added (including profits) and the final price is the return to stumpage. In order to justify plantation production the return to stumpage should be at least equal to the costs of production.

Several studies have been conducted that demonstrate the application of the conversion returns approach to the fuelwood subsector in African countries. These studies generally show that the returns to fuelwood marketing are high, principally because the value attached to, and actually paid for, stumpage is zero. Rents which should accrue to the owner of stumpage, in this case the general public, are instead captured by the entrepreneur as extranormal profits.

An example of the conversion returns approach to firewood is given in Table 12, based on a study published in Le Developpement Voltaique (1976). Table 12 shows the costs and revenues involved in the annual operation of a cart hauling fuelwood from natural stands into Ouagadougou, Upper Volta. As can be seen, fuelwood marketing is very profitable (net income to sales ratio of 80 percent), and made even more profitable by the fact that there is no stumpage fee imposed on the merchant.

If this approach were used to set stumpage fees, a "fair profit rate" would be selected (based on either sales revenue, capital investment or costs) and would be subtracted from the net revenue shown in Table 12. This "fair profit rate" would normally be selected to reflect profits in other sectors of the economy. This stumpage fee would then be charged harvesters by forest management authorities. The fact that this is not done reflects the treatment of wood from natural stands as having no value. It is important to note that this underpricing of natural stumpage is one aspect of the common property view of forests and serves to make forest mining especially lucrative, hastening deforestation. If a positive return to stumpage is enforced through some sort of administratively determined cost plus pricing mechanism, the derived stumpage price can be compared with the cost of plantation-grown wood.

The use of this approach in project analysis is illustrated by the World Bank appraisal of the Malawi Second National Rural Development Program (Wood Energy Project). The analysis first observed that the approaches discussed above (market prices and alternative fuels) either did not yield sensible results or could not be employed because of data problems. It was then determined to estimate the minimum value of the wood, based on appropriately shadow priced inputs, which, when discounted, would just cover project costs. The objective of this approach was to estimate an economic wood price that could be compared with prices for alternative energy sources.

TABLE 12

ANNUAL REVENUES AND COSTS TO FUELWOOD MERCHANTS IN UPPER VOLTA (1976)

(CFA)

Revenues		390,000
Direct Charges		
Food allowance for driver	12,000	
Feed for draft animal	18,000	
Benefits for driver	8,000	
Equipment maintenance	2,255	
Subtotal		40,255
Indirect Charges		
Driver salary	18,000	
Amortissement	15,030	
License for cart	4,000	
Subtotal		37,030
Net Revenues		312,715

Using all direct project costs as the basis for calulation and a 15 percent discount rate, it was determined that the break-even price of project output would be Malawi Kwacha (MK) 16.0/m^3. When compared with energy price equivalents of MK 36/m^3 and MK 28/m^3 for kerosene and coal, respectivley, the proposed project was deemed desirable. For examples of the cost of production approach applied to fodder production from agroforestry projects, see ILCA (1980).*

E. Time Spent Gathering Wood

One consequence of overexploitation of timber resources that has spurred interest in agroforestry is an observed increase in the amount of time expended to obtain fuel. Obviously this commitment of labor limits time available for other directly productive activities (such as crop production) and indirectly productive activities (such as other domestic chores, schooling and leisure time).

Given this, an appropriate way to value wood would be to estimate an implicit wage rate for family members. Assuming that the value of the last unit of wood collected must at least equal the implicit wages foregone, a value for wood can be easily calculated knowing only the amount of wood collected and the time spent on collection. Presumably, if additional wood is valued more than the additional wages or output foregone, then more time would be devoted to collection until marginal cost equals marginal benefit. The calculation of an implicit wage rate is also useful in calculation of project cost especially when labor-intensive techniques are employed.

Despite its intuitive appeal this approach has found only limited application in the analysis of agroforestry projects. One example is offered in Sheikh and Larson. In order to value both labor time saved and labor input to plantation production, Sheikh and Larson consider peak and off-peak labor, depending on the labor requirements of agricultural crops. Each type of labor is valued at a wage rate estimated from market wages, productivity in agriculture, or the judgement of the analyst supplemented by local input. For issues and approaches involved in estimating shadow wage rates, see Kao, Anschel and Eicher (1964), Gittinger (1972) and Sheikh and Larson (n.d.)

Sheikh and Larson also propose valuing adult and child labor at different rates implying different opportunity costs. This is done by simply adjusting either the wage or the time of children by a factor that takes into account different levels of productivity.

Once converted into cash units, labor time can be directly used in benefit-cost calculations. Clearly, the same wage rates should be used in calculating labor costs and benefits. Equivalently, net labor savings can be calculated for each year of the life of the project.

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*Note that this approach does not result in an explicit accept/reject conclusion nor does it allow calculation of internal rate of return. In fact if a price is calculated as shown above and then used to evaluate the project the PNW will be zero and the IRR the original discount rate.

Practical implications of this approach for the results of the benefit-cost analysis arise from technical requirements of plantation production and from the way in which farm labor time allocation has typically incorporated firewood collection, as discussed above. Under most conditions, especially arid climates, it is critical that seedling planting take place within relatively narrow time constraints in order to receive maximum benefit from the onset of rains. Unfortunately, this time tends to be the peak agricultural labor period. Several years after, when the forest crop is harvested, the benefits occur during the remainder of the year when demand for labor is slack and wages are low.

Agroforestry projects thus face two difficulties in discounted cash flow analysis when labor time is employed as the principal valuation tool. First, projects tend to consume high-value labor and to release low-value off-peak labor. Therefore, nonlabor costs aside, projects must release more than an equal number hours of time to be justified. Moreover, the discounting of net time savings that occur later at the date of harvest requires even larger time savings to justify projects.

A major problem in applying this approach is procurring data that reasonably reflect the actual amount of time that is spent on various activities throughout the year. Without these data, estimation of implicit wage rates and of the actual time savings that projects would generate is extremely difficult if not impossible. Collection of these data is a time-consuming and costly procedure which must be done over an extended period of time.

An additional difficulty is the determination of the actual impact of the project on labor allocation and output. For example, time spent in the collection of wood may have other joint uses such as foraging for wild foodstuffs, or socializing. Thus, even if firewood collection is completely eliminated, the amount of labor time released for new uses may be less then expected.

Related to this is the intensity of labor spent on wood gathering versus alternative activities. If wood collection is a particularly onerous task relative to the alternative of field work, for example, then the implied equivalent of time spent in each pursuit may not hold. Not only might the reallocation of labor result in incremental food output, but people might, in addition, be willing to pay to avoid wood gathering. Alternatively, if wood gathering were replaced by an even more objectionable task, hauling water, then the value of incremental wood would need to be reduced.

MERIT WANTS

Another set of unpriced values that are often relevant to agroforestry projects are nonmonetary social values that reflect normative judgements of the way things ought to be. Examples are the goals of rural energy self-sufficiency, equity, reducing the total labor requirements of women, and the aesthetic value of a landscape with trees. In economic parlance these values are termed "merit wants" and are difficult if not impossible to quantify to everyone's satisfaction. Nonetheless they are perfectly legitimate objectives for policy and are relevant to investment decision making.

As with many environmental benefits, projects can often be justified without resorting to incommensurables. Similarly, when readily quantifiable benefits fail to justify projects, it is appropriate to consider the magnitude of other benefits that would change the result. Thus, essentially political judgements are required to determine whether benefits reach the required level or not. While goals or merit wants such as these underlie many agroforestry projects, they have not been specifically addressed in quantitative project appraisal.

INVESTMENTS IN INSTITUTIONS

In order to develop viable agroforestry projects in most developing countries, there is a critical need for improvements and changes in a wide range of institutions. As noted earlier, the World Bank and UNDP have calculated that the equivalent of 15 percent of total fuelwood forestry investment requirements are needed for preinvestment work such as feasibility studies, training, research and development, and institution building. Part of this expenditure is required to simply expand the capability of small and underfunded forest management agenices. At the same time, though, additional resources are required to reorient existing agencies from activities (such as guarding forest) to new duties (such as providing extension services to small farmers). Other, even more general, changes in institutions related to forest resources (such as open access, common property ownerships) will be necessary in order to implement successful agroforestry projects on a large scale.

While making these changes are themselves investments, very little economic analysis is available to guide policymakers. This, in part, arises because of the difficulty of developing meaningful expectations about the returns to additional resources devoted to training or similar activities. Another problem is the difficulty of assigning the benefits of institutional improvement to particular projects as opposed to the operation of entire programs.

Conventional practice has been to focus project appraisal work on physical investments alone. Institutional and technical assistance components have generally had to be excluded from explicit benefit-cost analysis. Nonetheless, it seems likely that investments in institutions and human capital are among the best investments available in agroforestry in many developing countries.

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REVIEW OF AGROFORESTRY PROJECT DATA

by

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REVIEW OF AGROFORESTRY PROJECT DATA: PRODUCTION, INCOME, ENVIRONMENTAL IMPACTS

by
Steven Brechin

Economic evaluation of agroforestry projects is hampered by the relatively meager database available. It is difficult even to obtain very rough approximations of likely levels of benefits and costs. Therefore, we considered it useful to assemble in one place the quantitative data that we were able to collect.

The material is presented in two ways. First there are a series of tables that list the bare essentials of the data under the following categories:

Timber Production
Fuelwood Production
Crop Production
Fodder Production
Income
Soil Improvement
Environmental Protection

Most projects will appear in several parts of the table, depending on whether the project documentation provides specific data in each category. The tables contain information on the amount produced (or income or soil improvement, etc.), the project location, the general type of agroforestry systems, the crops and trees involved, and the date.

REVIEW OF AGROFORESTRY PROJECT DATA

by

Steven Brechin

Each entry in the tables is referenced to a note in the "Agroforestry Project Abstracts." This latter is the second form in which the material is presented. In the abstracts each project appears just once. The entries contain a very brief description of the project, the quantitative data found also in the tables, and the source of the information. Twenty-seven projects appear under twenty-two headings in the abstracts. Documentation on additional projects was collected but the information was not specific enough to serve the purposes of this compilation. Undoubtedly there are other sources we were not able to obtain. We hope the material that is presented will assist efforts to develop quantitative estimates needed for evaluating agroforestry projects.

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TIMBER PRODUCTION/YIELDS - Page 1

DATA		LOCATION	AGROFORESTRY SYSTEM	CROP(S)	TREE(S)	YEAR	NOTE #
1. 200 m^3/ha		Africa	Taungya	maize	Gmelina	1974	3b
2. 340 m^3/ha					Gemlina		
3. 280 m^3/ha					Terminalia		
1. 400 m^3/ha		"	"	"	Tectona		3c
2. 500 m^3/ha		"	"	"	Mahogany/Nauclea	"	"
123 - 128 m^3/ha	(E)	Cent. America	Tree/Crop	coffee	Cordia alliodora	N.A.	4a
5.5 - 5.6 m^3/ha/yr	"	"	"	"	"	78-79	6a
20.1 - 17.8 m^3/ha/yr	"	"	"	"	"	"	"
13.4 - 11.4 m^3/ha/yr	"	"	"	"	"	"	"
162.3 M^3/ha	(E)	"	"	"	"	1977	6b
189.0 m^3/ha	"	"	"	"	"	1978	"
1. 271.1 m^3/ha	(E)	"	"	cocoa	"	1. 1977	6c
2. 160 m^3/ha	"	"	"	"	"	2. ?	"
3. 169.5 m^3/ha	"	"	"	"	"	3. 1979	"
4. 168.7 m^3/ha	"	"	"	"	"	4. 1980	"
5. 85.0 m^3/ha	"	"	"	"	"	5. 1980	"
6. 141 m^3/ha	"	"	"	"	"	6. 1977	"
7. 134 m^3/ha	"	"	"	"	"	7. 1979	"

TIMBER PRODUCTION/YIELDS - Page 2

DATA		LOCATION	AGROFORESTRY SYSTEM	CROP(S)	TREE(S)	YEAR	NOTE #
1. 29.2 m^3/ha	(O)	Asia	Taungya	N.A.	Albizia falcataria	1975-1979	10a
2. 5.3 m^3/ha	"	"	"	"	"	"	"
3. 250 m^3/ha	(P)	"	"	"	"	"	"
4. 706.250 m^3/ha	"	"	"	"	"	"	"
1. 146 m^3/ha	(E)	Cent. America	Tree/Crop	coffee	Cedrula odorala	N.A.	18a
2. 214 m^3/ha	"	"	"	"	"	"	"
3. 132 m^3/ha	"	"	"	"	"	"	"
4. 100 m^3/ha	(P)	South America	Tree/Animal	grasses	Cordia alliodora	N.A.	18a
5. 450 m^3/ha	(P)	Asia	Taungya	N.A.	Teak	1977	18a
6. 11 m^3/ha/yr	(O	Cent. America	Tree/Crop	coffee	Cordia alliodora	1976-1977	18a

FUELWOOD PRODUCTION - Page 1

DATA	LOCATION	AGROFORESTRY SYSTEM	CROP(S)	TREE(S)	YEAR	NOTE #
(P)	Africa	Taungya	N.A.	Greuillea robusta Leucaena leucucaphala Sebenia grandiflora	N.A.	2
4.5 m^3/ha	"	"	"	"	"	"
1/2 - 1 m^3/ha/yr (hedge)	"	"	"	"	"	"
(O)	Middle East	Windbreak	N.A.	Canocarpuls lancifolius	N.A.	11a
1. 350 m^3/km	"	"	"	"	"	"
2. 17 m^3/km/yr	"	"	"	"	"	"
3. 80 kg/tree/yr	Asia	Tree/crop	N.A.	Prosopis cineraria	"	"
(P) 4. 15 - 25 m^3	Middle East	Trees on ag land	N.A.	Scrub	N.A.	"
(P) 5. 4.7 to 6.5 m^3/ha	"	"	veg. crops	Tamarix. spp.	"	"
0.8 to 1.2 m^3/ha	"	"	"	"	"	"
(P) 6. 0.6 - 1.0 m^3 400 meters/yr	Asia	Trees on ag. land	Rice	Combretum guadrangular	"	"
7. 7 - 9 m^3/ha/yr	"	"	N.A.	Albizia falcataria	"	"

CROP PRODUCTION/YIELD - Page 1

DATA		LOCATION	AGROFORESTRY SYSTEM	CROP(S)	TREE(S)	YEAR	NOTE #
1. 5,500 kg/ha	(O)	Africa	Taungya	1. maize	Gmelina	1974	3d
2. 25,000 kg/ha	"	"	"	2. cassava	"	"	"
3. 500 - 1000 kg/ha	"	"	"	3. maize	"	"	"
4. 5 - 10 tonnes/ha	"	"	"	4. yams	"	"	"
5. 10 - 15 tonnes/ha	"	"	"	5. cassava	"	"	"
1. 28,000 lb/ha	(E)	Cent. America	Tree/Crop	coffee	Erythrina poeppigiana	N.A.	4b
2. 12,600 lb/ha	"	"	"	"	"	"	"
3. 14,700 lb/ha	"	"	"	"	"	"	"
4. 66 tonnes/ha	"	"	"	sugarcane	"	"	"
_30 metric tonnes/ha	(P)	Asia	Tree/crop	Dioscorea (root crop)	mixed	1975	8a
40% increase		Africa	Windbreaks	cereal grain	N.A.	N.A.	9
245 kg/ha (Aug) increase	(O)	Africa	Windbreaks	millet	Azadirachta indica	1979	16b
29% Avg. increase		"	"	"	"	"	"
362 kg/ha/yr	(E)	South America	Tree/crop	Beans	Prosopis juliflora	1968-1969	18b
40 kg/hive/yr		"	"	Honey	"	"	"

CROP PRODUCTION/YIELD - Page 2

DATA		LOCATION	AGROFORESTRY SYSTEM	CROP(S)	TREE(S)	YEAR	NOTE
1,200 kg/ha	(O)	Africa	Taungya	maize, manioc yams	Eucalyptus Gmelina	1977	21
15,000 kg/ha	"	"	"	"	"	"	"
8,000 kg/ha	"	"	"	"	"	"	"
1. 1,680 kg/ha	(E)	Africa	Tree/Crops	maize	Leucaena leucocephala	1980	22
2. 1,744 kg/ha	"	"	"	"	"	"	"
3. 1,786 kg/ha	"	"	"	"	"	"	"
4. 1,337 kg/ha	"	"	"	"	"	"	"
5. 1,678 kg/ha	"	"	"	"	"	"	"
1. 483 kg/ha	"	"	"	beans	"	"	"
2. 396 kg/ha	"	"	"	"	"	"	"
3. 363 kg/ha	"	"	"	"	"	"	"
4. 410 kg/ha	"	"	"	"	"	"	"
5. 401 kg/ha	"	"	"	"	"	"	"

FODDER PRODUCTION/YIELD -

DATA		LOCATION	AGROFORESTRY SYSTEM	CROP(S)	TREE(S)	YEAR	NOTE #
1. 10-24 metric tons/ha/yr	(E)	Asia	Tree/animal	---	Leucaenu leaecocephla	N.A.	7
2. 67/-95 "	"	USA	"	"	"	"	"
3. kg/tree/yr		Asia	Trees on Ag Land	N.A.	Prosopis cineraria	N.A.	11b
15% Protein	(0)	Asia	Tree/animal	---	Acaica arabica	"	"
15% "	"	"	"	"	Ceratonia siliqua	"	"
15% "	"	"	"	"	Cleaitchia triaconthus	"	"
1. 240 kg/ha	(0)	USA	Tree/Animal	forage	Pinus palustris Pinus caribbea	1949	13a
2. 290 kg/ha	"	"	"	"	"	"	"
3. 595 kg/ha	"	"	"	"	"	"	"
1. 5-6 tons	(0)	Cent. America	Tree/animal	---	Psidiumguajava	1978	18c
2. 9 tons/ha/yr	(E)	South America	Trees on Ag Land	"	Prosopis juliflora	N.A.	"

INCOME - Page 1

RESULTS		LOCATION	AGROFORESTRY SYSTEM	CROP(S)	TREE(S)	YEAR	NOTE #
CROP SALE OR WORTH							
US$250/ha (farmer)	(O)	Africa	Crops in Greenbelt	groundnuts, pea, gombo, niebe	Eucalyptus Azadirachta indica Cassia siamea Gmelina arborea	1975-	1a
US$1500/ha "	"						
US$340/ha "	"						
US$145/ha "	"						
US$150/ha/yr	(E)	Africa	Taungya	melon, yams, pepper, tomatoes, okra, spinach, beans, cassava	Gmelina arborea	1974	3a
US$d50/ha/yr	"	"					
US$1000/ha/yr	"	"					
TIMBER SALE OR WORTH							
US$800/ha (farmer)	(O)	Africa	Taungya	"	"	"	3e
US$6.54/ha/yr "	(E)	Cent. America	Tree/crop	coffee, sugarcane	Cordia alliodora	1979	4c
US$354.64-85.08/ha/yr "	"	"	"	coffee	"	1978-1979	6a
P2,312/ha/yr "	(O)	Asia	Taungya	rice, corn, sweet potatoes	Alibizia falcataria	1975	8b
P1,679.80/ha "	"	Asia	Taungya	N.A.	Albizia falcalaria	N.A.	10b
P586.20/ha "	"	"	"	"			
P2,273.44/ha/yr "	"	"	"	"			

RESULTS		LOCATION	AGROFORESTRY SYSTEM	CROP(S)	TREE(S)	YEAR	NOTE #
TIMBER SALE OR WORTH (Cont.)							
US$374.68/ha/yr (farmer)	(P)	Cent. America	Tree/Crop	coffee	Cedrela odorata	N.A.	18E
US$580.99/ha/yr "	"						
US$357.91/ha/yr "	"						
US$1,833.33/ha/yr "	(P)	Asia	Taungya	N.A.	Teak	1977	18a
US$1790/ha (farmer)	(O)	Asia	Tree/crop	N.A.	Albizai falcalaria	N.A.	19
FUELWOOD SALE OR WORTH							
US$749.63/ha/yr (farmer)	(P)	Asia	Tree/crop	N.A.	Leucaena	N.A.	8c
ECONOMIC BENEFIT							
US$180/ha (project)	( )	Africa	Crops in Greenbelt	pea, groundnuts, gombo, niebe	Eucalyptus Azadirachta indica Cassia siamea Gmelina arborea	1975-present	1b
US$212.67/ha "	(E)	Cent. America	Taungya	Cucumis sativum Cucurbita maxima Manihot utilissima Phaseolus vulgaris Zea mays	Cordia alliodora	1963	6a

RESULTS		LOCATION	AGROFORESTRY SYSTEM	CROP(S)	TREE(S)	YEAR	NOTE #
ECONOMIC BENEFIT (Cont.)							
US$1076.11/ha (project)	(E)	Cent. America	Taungya	maize & beans	Gmelina arborea	1977	6e
US$272.25/ha/yr "	"	"	"	beans & greenbeans	Terminalia ivorensis	1979-1980	6f
US$145.32/ha/yr "	"	"	"				
P4,160.90/ha "	"	Asia	"	N.A.	Albizia falcataria	N.A.	10c
(project)	( )	Africa	Taungya	maize & beans	Pinus patula	1978	12
Shs 25,600/ha							
Shs 36,400/ha	Taungya						
Shs 47,600/ha							
Shs 21,900/ha							
Shs 13,200/ha on timber (control)							
(project)	(E)	Cent. America	Taungya	maize & beans	Gmelina arborea	1978	18f
9,190/ha							
COST SAVINGS		Africa	Taungya	groundnuts	Eucalyptus		5
50% production cost savings/tonne							
139% total cost savings/ha							
100% total cost savings/ha							

INCOME - Page 4

RESULTS	LOCATION	AGROFORESTRY SYSTEM	CROP(S)	TREE(S)	YEAR	NOTE #
COST SAVINGS (Cont.)						
500 - 800% project cost savings	Cent. America	Taungya	maize	*Cordia alliodora*	1974	6g
90% irrigation cost savings	Africa	Windbreak	N.A.	*Prosopis chilensis* *Conocarpus tancifolius*	1977	15

RESULTS		LOCATION	AGROFORESTRY SYSTEM	CROP(S)	TREE(S)	YEAR	NOTE #
SOIL FERTILITY							
80 kgs N/ha		Cent. America	Tree/crop	coffee	*Erythrina poeppigiana*	1979	6n
100 - 300 m^3		Africa	Trees on ag. land	millet	*Acacia albida*	N.A.	11c
0.125% Nitrogen		Africa	Taungya	maize, yam, cassava	*Gmelina arborea*	N.A.	14
7.99 ppm Phosphorous		"	"	"	"	"	"
Elements	kg/ton	(E)					
Nitrogen	20 - 36		Tropical	---	---	*Leucuena*	---	17
Phosphorous	1.5 - 3.0		"	"	"	"	"	"
Potassium	13.4 - 23.7		"	"	"	"	"	"
Calcium	7.5 - 20.3		"	"	"	"	"	"
Magnesium	3.9 - 9.8		"	"	"	"	"	"
20 lb/acre/yr		(E)	Cent. America	Tree/crop	coffee	*Erythrina poeppigiana*	N.A.	18g
SOIL MOISTURE							
20% decrease in H_2O evaporate		(E)	Arid Lands	Windbreaks	N.A.	N.A.	1953	9
WIND REDUCTION							
1. 22 - 53%		(O)	Africa	Windbreak	millet	*Azadirachta indica*	1979	16
2. 33 - 62%		(O)	"	"	"	"	"	"

ENVIRONMENTAL PROTECTION - Page 1

DATA		LOCATION	AGROFORESTRY SYSTEM	CROP(S)	TREE(S)	YEAR	NOTE #
EROSION CONTROL	(E)	Cent. America	Tree/crop	coffee	*Cordia alliodora* *Erythrina poeppigiana*	N.A.	4d
1. 313 kg/ha control	"	"	"	"	"	"	"
2. 41 kg/ha	"	"	"	"	"	"	"
3. 67 kg/ha	"	"	"	"	"	"	"
TREE PLANTING							
11,300,000	(O)	Asia	Taungya	N.A.	*Albizia falcataria*	1969-1980	10d

AGROFORESTRY PROJECT ABSTRACTS

1. GREENBELT AROUND OUAGADOUGOU, UPPER VOLTA

Multiple objective greenbelt project (plantation) surrounding capital city Ouagadougou, Upper Volta. Started in 1975. Width 500 meters. Addition of 120 ha/yr. (800 ha to date). 4 x 4 meter formation. Crops: groundnut (Carachides-arachis hypogea); gombo (Hibiscus esculentus); pea (Voandzeia subterranea); niebe (Vigna uniquiculata/sinensis). 39% of Greenbelt under peanut cultivation. Average field size: 1000m^2.

a. Income: Crop Sale or Worth

U.S. currency based on 280 CFA = 1$.

1. Groundnuts: 70,000 CFA/ha.
2. Gombo: 700,000 CFA/ha
3. Pea: 97,000 CFA/ha
4. Niebe: 410,000 CFA/ha

No date given for prices. Prices based on quotation from Regional State Development Organization.

b. Economic Benefit

Based on planting of Eucalyptus camadulensis (high yield tree). Six-year rotation period. 12% interest rate. -49,000 CFA/ha/yr loss without intercropping. With intercropping 50,000 CFA/ha (six years) net benefit. (U.S. $180/ha).

Source 1: Weinstabel, Peter. 1982. "Agroforestry Aspects Concerning the Establish ment of the Greenbelt Around Ouagadougou." German Upper Volta Forestry Project.

2. TAUNGYA IN KENYA

Taungya system in Kenya, Africa. Projected fuelwood production 4-5 m^3/ha. (no mention of time). Based on principle of 1/5 to 1/4 volume of tree same species produced in fall plantation (Grevillea robusta). With hedge: no species given. 1/2 - 1 m^3/ha/yr. This is based on estimate of well established hedge 200 m hedge/ha.

When combining fuelwood and fodder objectives expect 1/8 to 1/18th less fuelwood output of woodlot covering comparable area.

Source 2: Van Geld, B. and Poulsen, G. 1982. "The Woodfuel Supply from trees Outside the Forests in the Highlands of Kenya." The Beijer Institute. The Royal Swedish Academy of Sciences. Stockholm, Sweden.

3. TAUNGYA IN NIGERIA

Taungya system in the highlands of Nigeria. Reforestation efforts: 40,800 ha/yr. These areas available for cultivation. The project has areas where the forest service is working with peasant farmers in crop production and areas where forest service is working without farmers in crop production.

a. Income - Crop sale (Projected average earnings)

$150/ha/yr. maize
$250/ha/yr. cassava
$1000/ha/yr. yams

b. Timber Production(Yield)

1.	200 m^3/ha	7 year rotation	Gmelina	pulpwood	(main)
2.	200 m^3/ha	15 year rotation	Gmelina	timber	(main)
	140 m^3/ha	"	"	"	(thinning)
3.	280 m^3/ha	30 year rotation	Terminalia	"	(main)

Timber/pulp estimated based on intercropping of maize and cassava.

c. 1.	200 m^3/ha	60 year rotation	Tectonu	timber	(main)
	200 m^3/ha	"	"	"	(thinning)
2.	200 m^3/ha	70 year rotation	Mahogany/ Nauclea	"	(main
	300 m^3/ha		"	"	(thinning)

Timber estimates based on intercropping with peasant farming maize, cassava, and yams.

d. Crop yields

1. 5,500 kg/ha maize
2. 25,000 kg/ha cassava

Experiments by Forest Service with use of improved strains and fertilizer. Results based on experimental plots. Maize: 5 times normal; cassava: 2 times normal.

3. 500 - 1000 kg/ha maize
4. 5 - 10 tonnes/ha yams
5. 10 - 15 tonnes/ha cassava

Not experimental plots: Farmers consume 25 to 75% (50% avg.) of output.

e. Timber sales

U.S.$800/ha production of Gmelina. 7-8 year rotation.

The article's thesis was to demonstrate the financial wisdom of combining agriculture with timber production: more profitable.

Source 3: Lowe, R. G. (no date), "Far Forestry in Nigeria." Federal Department of Forest Research. Ibadan, Nigeria.

4. COFFEE WITH LAUREL AND PORO IN COSTA RICA

Coffee (Coffea arabica) with Laurel (Cordia alliodora). Erosion control experiment with coffee and poro (Erythrina poeppigiana).

a. Timber production(yield)

123 - 128 m^3/ha Based on merchantable wood volume (laurel) on hectare of coffee/tree plantation.

b. Crop production(yield)

1. Caturra variety
2. Borbon Arabica varieties
3. Borbon variety
4. Sugarcane with laurel (*Cordia alliodora*).
   Control plot of cane only (no trees): 77 tonnes/ha.

c. U.S. $6.54/ha/yr (1979) sale value of laurel.

d. Environmental Protection

1.	313 kg/ha	Erosion.	control: *Coffea arabica* only.
2.	41 kg/ha	"	coffee with *E. poeppigiana*
3.	67 kg/ha	"	coffee with *E. poeppigiana* and *Cordia alliodora*

Timber production information based on: Combe, J. and Gerwald, N. "Gwia de campo de ols ensayos forestales del CATIE en Turrialba. Costa Rica, CATIE, (1979) 379 p.

Source 4: Beer, J. W., Clarkin, K. L., Delas Salas, G. and Glover, N. L. 1979. "A Case Study of Traditional Agroforestry Practices in A Wet Tropical Zone: The 'La Suiza' Project." Centro Agronomico Tropical De Investigation y Ensenanza (CATIE) Costa Rica: and the United Nations University.

5. TAUNGYA IN UGANDA

Projected cost saving between Taungya and non-agroforestry efforts. Source frequently noted that crop production in association with tree production, significantly reduce plantation costs.

Income

Cost Savings (Production)

1. US$4 tonne without Taungya system.
2. US$2 tonne with Taungya system.

50% cost savings based on production cost of fuelwood. *Eucalyptus* (site index 30) Coal equivalent. See Kingston, B. (1972) "Growth yield and rotation of seedling crops of *Eucalyptus grandis* in Uganda." *Technical Note 193/72*. Uganda Forestry Department, Entebbe.

Cost Savings (Total Project)

	Rotation years	w/o Taungya Total Cost/ha	w/Taungya Total Cost/ha
139%	5	299	125
100%	6	383	190

Growing cost of fuelwood in Uganda in man/days. Based on 299 (5 year) and 383 (6 year) total cost/ha (w/o taungya). 125 and 190 total cost/ha.

Source 5: Earl, D. E. 1975. Forest Energy and Economic Development. Clarendon Press. Oxford.

6. TAUNGYA IN COSTA RICA

Taungya System in Costa Rica. Included in these cases are tree/coffee association along with intercropping of crops with tree plantation.

Timber Production/Yield/Income: Timber sale of worth

a. Annual volume increase of laurel (w/coffee) as an economic value in 3 sites of the Turrialba area.

		Laurel density ha	Volume increment m^3/ha/yr.	Value of timber increment $/ha/yr.
Site 1	H	410	5.5	351.64
	M	120	5.6	358.03
Site 2	H	270	20.1	1285.08
	M	180	17.8	1138.03
Site 3	H	340	13.4	856.72
	M	180	11.4	728.85

Experiment of 3 sites with high and medium density of laurel. The Economic results were 10 - 30% greater than non-shaded coffee. Results from research by Gonzalez (1980) "Efecto de la asociacion de laurel (Cordia alliodora) Oken Sobre la produccion de cafe (Coffea arabiya) con y sin sombra de poro (Erythrina poeppigiana). Thesis mag. sc. Turrialba, Costa Rica, UCR/CATIE. 110 p. 66 ref.

b.

	1977	1979
	15 years	17 years
No. of trees/ha:	288	228
Total Volume m^3/ha:	162.3	189

Volume given with bark. Laurel trees on coffee plantation. Growth of natural stand over coffee shaded by Erythrina poeppigiana.

c. Laurel with cocoa. (Theobroma cacao). Natural stand of 20 - 25 years of age. Results based on.

1. 120 trees/ha
2. 180 trees/ha
3. 187 trees/ha
4. 180 trees/ha
5. 76 trees/ha
6. 120 trees/ha
7. 100 trees/ha

Income
Economic benefit

d. Taungya System in Costa Rica. In the experiment, laurel trees were planted in 1961. 3 x 3 in spacing. Crops planted on two successive rotations. The project produced (gross) benefit of 1410 colones/ha/yr. (1963: 6.63 colones = 1US$ in the second year of the project.

e. Experimental Taungya system in Costa Rica. 1977. No fertilizer used. 1/2 trees planted were stumps other 1/2 seedlings. Beans and maize - 2 plantings with Gmelina
Net benefit of 9190 colones/ha 1 US$ = 8.54 colones.
Net benefit: US$ 1076.11/ha - after second year.

f. Economic benefit of Taungya System in Costa Rica. Terminalia with beans and greenbeans. Greenbeans followed beans in planting. Trees planted in June 1978 with 3 x 3 in. spacing. 1/2 were stumps, the other 1/2 seedlings. No fertilizer used.
Net benefit (project) 2325/ha/yr. colones.
Colon fluctuated between 8.54 to 16.00 for 1 US$ in 1979 - 1980.
Consequently range $272.25/ha/yr. to 145.32/ha/yr.

g. Cost Savings

Experimental Taungya System in Costa Rica. Laurel trees. Spacing 2.5 x 2.5 m used stumps and seedlings. Both 13 months old. Laurel (Cordia) with maize reduce project cost 5 - 8 times than Laurel alone. No cost data given. (500 - 800%)

h. Soil Fertility

Nitrogen production from leaves/flowers of E. poeppigiana in coffee plantation in Costa Rica. The experiment presented results of 80 kg N/ha. The report never cited number of trees/ha. Coffee plants spaced 6 - 10 m apart. Nitrogen concentration in leaves varies between 4.2 to 4.6% dry weight. Based on research by Molleapaza, A.I.E. (1979) "Produccion de biomasa de poro Erythrina poeppigiana O. F. cook y del laurel (Cordia alliodora) oken asociado con cafe. Tesis Mag. Sc. Turrialba, Costa Rica. UCR/CATIE.

Source 6: Budowski, G. 1981. "Quantification of Current Agroforestry Practices and Research Plots in Costa Rica." Centro Agronomico Tropical De Investigacion y Ensenanza. Turrialba, Costa Rica.

7. LEUCAENA FOR FODDER IN THE PHILIPPINES AND HAWAII

a. 10 - 24 metric tons/ha/yr. (dry weight) - leaves of Leucaena were produced in a tree/animal system in the Philippines. The experiment was conducted by the University of Philippines, College of Agriculture. That level of fodder can support 6 - 18 steers at 50% feeding of fodder. No other details given.

b. Experiment in Hawaii produced 67 - 95 mt/ha/yr. (fresh weight) of Leucaena leaf fodder. The fodder processed into leaf meal. It was estimated that level of production could support 12 - 18 steers at 50% fodder feeding. It was noted maximum forage yield - 100,000 to 130,000 plants/ha would be required.

Source 7: International Consultation on Ipil - ipil Research. 1976. Management and Utilization for Forage and Soil Amelioration." Output of Task Force No. 3. U.S. National Academy of Sciences and Philippine Council for Agriculture and Resources Research.

8. LEUCAENA IN THE PHILIPPINES

a. Crop Production/yield

Tree/crop association in the Philippines. Results projected on intercropping Dioscorea (root crop) under normal forest canopy. It was noted higher yields could be expected when planted under Leucaena.

b. Timber Sale or Worth

P2,312.00/ha/yr. from Taungya System in the Philippines. Figure from Paper Industries Corporation of the Philippines (PICOP) payment of farmers for timber production. The figure does not include intercropping of maintenance crops. P = Philippine currency (exchange rate not given for 1975). Note: Leucaena has higher value for fuelwood/charcoal then Albizia.

c. Fuelwood Sale or Worth

Figure based on agroforestry system in the Philippines. Farmers sold at roadside average P 5, 622.21 ha/yr (US749.63/ha/yr) (P 7.5 = 1 US$ 1976). Leucaena.

Source 8: International Consultation in Ipil-ipil Research. 1976. "Management and Utilization of Leucaena species for Wood Production and Ecosystem Improvement." U.S. National Academy of Sciences and Philippine Council for Agriculture and Resource Research.

9. WINDBREAKS IN AFRICA

General information regarding the effect of windbreaks on the total yield of cereal grains grown in arid regions.

Source 9: FAO. 1977. "Savanna Afforestation in Africa." FAO Forestry Paper No. 11. United Nations Food and Agriculture Organization. Rome. pg. 177.

10. PAPER INDUSTRIES CORPORATION OF THE PHILIPPINES (PICOP) PROJECT

a. Timber Production and Yield

Figures from a PICOP project consisting of 23,600 hectares involving 3,800 farmers.

1) 660,579 m^3 pulpwood - not fully matured (29.2 m^3ha - based on 22,600 ha)

2) 119,932 m^3/ha 1980 - 1st 6 month production. (5.3 m^3,ha - based on 23,600 ha)

3) 250/m^3/ha Average production on 8-year rotation.

4) 760,250 m^3/ha/yr. projected 8-year rotation. 22,600 ha. 4 x 4 meter spacing.

b. Timber Sale or Worth

1) P1679.8/ha Based on the 1975 - 1979 sale. 660.579 m^3 pulpwood (not fully matured) at a gross sale of P 37,963.544 over 22,600 ha.

2) P586.20/ha Based on the 1st 6 months of 1980. 119,932 m^3 sale of pulpwood of a gross sale P 13,248,637.00 over 22,600 ha.

3) 2,273.44/ha/yr. Based on rate P 72,75/m^3 x 706,250 m^3/yr average production. 22,600 ha.

c. Economic Benefit

P4,160.90/ha Net income at 9th year. Based on gross income (Average harvest 250 m^3/ha with selling rate of (P72.75 m^3) = (P 18,185.50). Income total cost (P14,026,60) for the establishment, maintenance one hectare. (Planting, harvesting, hauling, debarking, 12% interest and taxes.)

d. Environmental Protection

11,300,000 trees planted from 1969 to 1980. Began with 22 demonstration farmers to 3,800 farmers in 1980. Part of the PICOP forestry program.

Source 10: Metela, A. G. (no date) "The Agroforestry Development Plan and Practices of PICOP." Paper Industries Corporation of the Philippines.

11. FUELWOOD, FODDER, AND SOIL IMPROVEMENT

a. Fuelwood Production - Trees on Agricultural Lands

1) 350 m^3/km after 20 years. Established on alluvial soils under irrigation (2 rows).

2) 17 m^3/km/yr. Average per year. (20 years). Observations from Yemen. Trees along irrigation canals to protect crops and provide fuelwood.

3) 80 kg/ha/yr After 15 - 20 years (branches) *Prosopis* planted on ag. lands to improve soil fertility.

4) 15 - 25 m^3/5 years of fallow (no unit of area given). Fuelwood from scrub brush in Iran.

5) 4.7 to 6.5 m^3/ha. 3 to 4 year period based on 200 trees/ha of *Tamarix spp.* Trees planted around vegetable crops. Tree roots provide 0.8 to 1.2 m^3/ha.

6) 0.6 - 1.0 m^3/400 linear meter/yr. 1st cutting. Projection. Combretum grown along the dikes of rice patties (1 ha sq). 2 rows of Combretum at 1.5 x 1.5 meter spacing. Managed under coppice system. Rotation of 5 to 6 years. In second or third rotation, production may double. Under this system, farmers can cut 1/5 to 1/6 of total length of dike a year.

7) 7 - 9 m^3/ha/yr. Estimated average fuelwood production on farm yards in one watershed in Java. 63% fuelwood production was from farm yards (E. Java). 49 to 81% in Central Java.

b. Fodder Production/Yield

3 kg/tree/yr. after 15-20 years average fodder from leaves. Trees planted in agricultural lands for improving soil fertility.

c. Soil Improvement

100 - 300 m^2 area affected by nitrogen-fixing tree (Acadia albida). The tree planted in millet fields to improve yields. 100 trees/ha sufficient to maintain indefinitely the nutrient requirements of the cropland.

Source 11: Salem, B. B. and Tran Van Nau. 1981. "Fuelwood Production in Traditional Farming Systems." Unasylva. FAO. Rome.

12. TAUNGYA IN TANZANIA

Economic benefit of Taungya System in Tanzania. The income differences based on varying conditions. 5% value of all future rotations at present values. Based on 1978 prices. Wood production only (control) 13,200 shs/ha. Assumed the cost of labor of subsistence farmers is zero.
Note: Taunagya has been shown to distribute more benefits to the poorest strata of the society.

a. 25,600 shs/ha. Taungya System with planting of trees the 1st rainy season after clearfelling and food production for two years after planting.

b. 36,400 shs/ha. Taungya System with 2 years of cultivation before trees are planted and three years after.

c. 47,600 shs/ha. Taungya System with 5 years of cultivation before trees are planted and three years after.

d. 21,900 shs/ha. Agro-silvicultural combination by paid labor. Planting of trees the 1st rainy season after clearfelling and beans productions for two years after plants.

Source 12: Hofstand, O. 1978. "Preliminary Evaluation of the Taungya System for Combined Wood and Food Production in North Eastern Tanzania." Division of Forestry. University of Dar es Salaam.

13. FODDER

a. Forage Production/Yield

Observations of forage production in forested areas with varying degree of stand density, Mississippi, U.S.A., 1949.

1) 240 kg/ha (maximum) w/ density 750 trees more than 10 cm diameters/ha.

2) 290 kg/ha (maximum) w/ density 560 trees/ha.

3) 595 kg/ha (maximum) w/ density 75 trees/ha

Note: In comparatively hot/dry climates possible to have greater amounts of forage to be produced under a fairly dense stand compared to open and untimbered ground.

In the experiment the quality of forage in terms of dry weight protein level. Varied 10.37 - 13.14%.

b. Observations regarding the crude protein levels of the dry weight of leaves of Acacia, pods and seed of Ceratonia, and fruits of Cledlichia.
See: 1. M. U. Laurie. (1939) Fodder Trees of India.
2. J. Russel Smith. (1950) Tree Crops. A Permanent Agriculture. The Devin Adair Co. New York.

Source 13: FAO. 1953. Grazing and Forest Economy. FAO Forestry and Forest Products Studies No. 4. Food and Agriculture Organization of the United Nations.

14. TAUNGYA IN NIGERIA

Taunagya Systems in Southern Nigeria. Experimental farms were established in three ecological zones to study the effects of agroforestry on soil fertility. Each experimental area was divided into eight blocks of five plots each. Each plot was 20 m x 20 m:

- control: 0.128% Nitrogen (Average 8 plots) Gmelina alone.

- 0.125% Nitrogen (Average 32 plots) Gmelina and combination of maize, yam, and cassava.

- control: 6.16 ppm Phosphorus (Average 8 plots) Gmelina alone.
7.99 ppm. Phosphorus (Average 32 plots) Gmelina and combination of maize, yams, and cassava.

Report concludes that crop production in forest plantations (Taungya) does not adversely affect soil nutrients and consequently tree production.

Source 14: Ojeniyi, S. O., O. O. Agbede and J. A. Fagbenro. 1980. "Increasing food production in Nigeria: 1. Effect of Agro-silviculture on Soil Chemical Properties." Soil Science. Vol. 130, No. 2.

15. WINDBREAK IN SUDAN

Observation from the El Zeidab and El Hassia pump scheme in Sudan. Farmland and irrigation system were jeopardized by desert encroachment. Windbreak established in 1972, protecting a narrow band of fertile farmland along the Nile. Windbreak was estimated to save 90% in maintenance cost, etc. of irrigation in 1977.

Source 15: Bayoumi, A. A. (No date) "Forestry and Rural Development: Some Examples From the Sudan." Sudan Forest Administration.

16. WINDBREAK IN NIGER

Windbreak system in Niger. Planted in 1975. Evaluated in 1979. Windbreak lines homogenous and well developed. Height of 7 meters. 2 rows rectangular. Spacing of 4 x 4 meter. Control site nearby with similar conditions.

Wind Reduction

Control		1h	5h	8.5h	12h	16h	Distance leeward from Windbreak
100	1.	78	47	60	72	63	Relative wind Velocity %
	2.	38	46	58	66	67	

1. 53 - 22% reduction at 1 meter height
2. 62 - 33% reduction at 2.5 meter height

Crop Production/Yield

Control Z	1h E	5h D	8.5h C	12h B	16h A	mean H-E	
854	1106	1332	1043	1070	944	1099	tg/ha
100	130	156	122	125	111	129	%

- Average Crop yield increase 29%
- 1099 kg/ha (Avg) production compared to 854 or a 245 kg/ha increase
- Correction for the cost of land to windbreak equals 6%. Overall increase 26%

Source 16: Bognetteau - Verlinden, Els. 1980. "Study on Impacts of Windbreak in Mayjia Valley, Niger." Unpublished Master Thesis. Agricultural University, Holland.

17. FORAGE AND GREEN MANURING

General Analysis of yield of forage and nutrients. For green manuring, the forage (leaves) can be chopped, spread over field, and tilled into the soil. In rice patties, leaves are harrowed in during land preparation prior to planting.

Source 17: International consultation on Ipil-ipil Research: Task Force No. 2. "Farming Systems." U.S. National Academy of Sciences and the Philippine Council for Agriculture and Resources Research.

18. TIMBER, CROPS, AND FODDER

a. Timber Production/Yield

1) Timber production of Spanish cedar (Cedrela)
Experiments based on 3 comparable sites of coffee/tree association.
Average volume in board feet and cubic meter. (25% bark)

Sites	Boardfeet	Cubic Meters/h
San Carlos	25,861	146
Tabarcia A	37,796	214
Tabarcia B	23,283	132

2) 100 m^3/ha - after 20 years of timber/forage.

Experiment to associate forage grasses with timber production in Ecuador. Trees planted at 5 x 5 meter spacing (400/ha). After planting, forage grasses are left. Fallow for one year or until timber trees are 3 meters high. After two years, trees are thinned to 200/per hectare and after 4 years thinned to 100/ha. Project to renovate lands suffering from deforestation from livestock.

Source: Bishop, I. P. "Livestock - Forestry Production in the Spanish American Humid Tropics." In Workshop. op. cit.

3) Taungya System in Northern Thailand. 450 m^3/ha includes thinnings.

Source: Chapman, E. C. "Trees and Shifting Cultivation in S.E. Asia: Towards Reunion Rather than Divorce." In Workshop. op. cit.

4) 11 m^3/ha/yr of commercial value timber. Mean annual increment for 228 laurel trees per hectare - based on natural regeneration at age 15.

Source: Combe, I. "Concepts of Agro-Forestry Research Techniques at CATIE." In Workshop - op. cit.

b. Crop Production(Yield)

1) Intercropping experiment in Peru. Plantation of mesquite based on 10 m x 10 m planting (1000) acres). Plantation irrigated by lateral channels - either by gravity or by tank. Beans were intercropped at a 0.30 m spacing between plants. 362 kg/ha/yr. production of beans in experiment. There were 3 harvest combinations of bean 40 and Zarandaja. The harvest was considered normal production, i.e. trees didn't affect output. Crops were irrigated 38 times at 80 m^3/ha for a total of 3,000 m^3/ha/yr at a depth of 12.5 cm water.

2) 40 kg/yr honey production from same project. Based on 2 harvest following the flowering periods of Prosopis. Honey output based on 30 beehives (10 hives in 1st year used for honey production. 20 hives used only for increasing the swarms.)

Source: Valdivia, S. U. and Aragon, L. J. "Settlement and Rural Development in the Eriazas zones of the North Coast of Peru." In Workshop. op. cit.

c. Fodder Production/Yield

Fodder from the fruit of the Psidium. Results of 5 - 6 tons/6 months period. Data collected from actual farm in the Turrialba district of Costa Rica. 300 Psidium trees on farm. Farm of 26 hectares. 23 ha in cattle production. The remainder in coffee. Fodder used to feed hogs. Need to substitute 8 lbs. of fruit (Psidium) for 3 lbs of maize.

Source: Avila, M., Ruiz, M. E. Pezo, D., Ruiz, A. "The Importance of the Forestry Component of Small Cattle Farmers in Costa Rica." In Workshop. op. cit.

9 tons/ha/yr. fodder from Prosopis. Data based on maximum production at 40 years. Plantation of mesquite (Prosopis) based on 10 m x 10 m planting (1000 acres). Plantation irrigated. Beans were intercropped.

Source: Voldivia, S. U. and Aragon, L. J. "Settlement and Rural Development in the Eriazas Zones of the North Coast of Peru." In Workshop. op. cit.

d. Income: Timber Sale or Worth

US$1,833.33/ha/yr. average gross income from the sale of teak in northern Thailand, based on 1977 dollar prices. The figure excludes the cost of harvest of US$400/ha/5 years. Data based on average teak production of 450 m^3/ha over 60 year period - including thinnings.

Source: Chapman, E. C. "Trees and Shifting Cultivation in S.E. Asia: Towards Reunion Rather than Divorce." In Workshop. op. cit.

e. The figures are projected average gross income. $0.23/pulgada tica for cedar logs (Cedrala). 1 pulgada tica = 0.00605 m^3. Average tree is 17 years. The figures correspond to the following stand densities (84, 141, 78).

Source: Ford, L. B. "An Estimate of the Yield of Cedrela odorala Grown in Association with Coffee." In Workshop. op. cit.

f. Income: Economic Benefit

Taungya experiment in Costa Rica. Figures based on local currency. c 9,190/ha (net income) over 10-month period. Based on 2 x 3 m spacing of Gmelina combined with maize and beans.

Experiment began in May 1977 and ended in April 1978. Gmelina planted under 8 different treatments. 4 plots with 2 x 1 m spacing (5,000/trees/ha). 4 plots 2 x 3 m spacing (1,600 trees/ha).. Fertilizer was not used. 2 plantings of crops. Treatments were:

1 x 2 m spacing
plantation alone
with maize
with beans
with maize and beans

2 x 3 m spacing
with same combinations (5 - 8)

Crops did not affect the development of the forest species.

Gmelina: due to rapid growth at 2 x 3 m spacing did not permit adequate crop growth during 2nd rotation (especially for maize). Consequently, the 4 lower branches of each Gmelina had to be pruned at age 6 months.

Treatment 2 (Gmelina at 2 x 1 m and maize) was only unprofitable agroforestry combination. However, the crop yields lowered plantation costs by 70% (compared to Gmelina alone in plantations.)

All other Taungya treatment crop yields (10 month period) covered all production/maintenance costs of the plantation - leaving net gains from c 8.25 to c 9.190 ha. Only precise data given to the last figure: Treatment eight: (Bean and maize at 2 x 3 spacing)

Source: Rosero, P. 1977. "Taungya Trial at CATIE with Gmelina arborea." In Workshop. op. cit.

g. Soil Improvement

The data from a study concerning the effects of poro (Erythrina) on soil fertility. 50 trees/acre. Nitrogen from falling flower/leaves. 20 lbs (9 kg) Nitrogen/acre. Equivalent to 180 kg/ha (200 lb/acre) of ammonium sulphate.

Source: Combe, I. "Concepts of Agro-Forestry Research Techniques at CATIE." In Workshop. op. cit.

Source 18: CATIE. 1979. Workshop Agro-forestry Systems in Latin America: Proceedings. Centro Agronomico Tropical De Investigacion y Ensenanza. Turrialba, Costa Rica

19. PICOP PROJECT IN PHILIPPINES

US$1790/ha based on 8 years. Net income. No date given. Sale of food crops not included. Crop incomes generally range from US$102 to 202/ha/yr. Project part of Paper Industries Corporation of the Philippines (PICOP). Pulp production projections involving peasant farmers in the Philippines.

Source 19: Polliso, F. (No date) "Agro-silviculture Concepts and Practices: The Philippine Experience." Forest Research Institute. Los Banos, Laguna, Philippines.

20. LEUCAENA IN KENYA

Income

Projection regarding the production of Leucaena as a cash crop on agricultural lands in Kenya. Source of fuelwood and fodder. The figure is an average yearly net balance of earning over 4 years.

	Year 1	Year 2	Year 3	Year 4	
Net Balance	975	3325	4500	4600	(KShs/ha)

The data assumes:
1. Farm gate price of Shs 800/ton.
2. Yield 5 ton/ha.
3. Cash costs include pesticides, transport, milling, and packaging of the meal (fodder).
4. The Shs/ha establishment costs are repaid over 3 years.

Source 20: Wake, N. L. 1978. "Leucaena, A Promising Small-Holder Crop with Export Potential for Coastal Kenya." (Prefeasibility Study). Industrial Survey and Promotion Centre, Ministry of Commerce and Industry. Nairobi, Kenya.

21. TAUNGYA IN NIGERIA

Taungya System in Southern Nigeria. Figure based on observation of traditional Taungya practices (farmers) yield:

1.	Maize (grained and dried)	1200 kg/ha.
2.	Manioc (fresh)	15,000 kg/ha.
3.	Yams (fresh)	8,800 kg/ha.

It was estimated that one hectare provided 82 - 140 mandays annually.

Source 21: Von Nau, Tran. 1978. "Agrisilviculture Joint Production of Food and Wood." Eighth World Forestry Congress. Jakarta, Indonesia.

22. _____

Experiments in agroforestry in Tanzania regarding crop yields. The figure represents 1st year yields of maize and beans. Spacing of Leucaena, 1 - 4 was as follows:

3 x 3 m, 4 x 4 m, 5 x 5 m, 6 x 6 m.

The yields of maize and beans were comparable with monoculture outputs. Maize 1,678 kg/ha^{-1}, beans 401 kg/ha^{-1}.

Source 22: Maghembe, J. A. Chingaipe, T. M. and LUlandala, L. L. L. 1981. "Agroforestry and Farming Systems. Role in Marginal Agricultural Areas." Division of Forestry. University of Dar es Salaam. Paper presented at the Farming Systems and Farming Systems Research Conference. Austria. April 14-16, 1981.

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