Small-scale farm forestry: an adoptable option for smallholder farmers in the Philippines?

M. Bertomeu

[1] World Agroforestry Center (ICRAF) ([*]Author for correspondence: ICRAF-Philippines, 2/F College of Forestry and Natural Resources Admin. Building, 4031 College, Laguna, Philippines; Phone: 63 49 5362925; E-mail: m_bertomeu1@terra.es)

Abstract

In the Philippines, smallholder farmers have become major timber producers. Farmers' intensive tree establishment and management practices ensure tree survival and growth. However, the systems of timber production practiced have several limitations. In intercropping systems, the practice of severe branch or root pruning reduces tree-crop competition and increases annual crop yields, but is detrimental to tree growth and incompatible with commercial timber production. In even-aged woodlots, lack of regular income and poor tree growth, resulting from farmers' reluctance to thin their plantations, are major constraints to adoption and profitable tree farming. Financial analyses showed that at current stumpage prices, smallholder agroforestry systems that produce low quality timber are not a viable alternative to maize farming. On the other hand, higher returns to labor and capital invested from intercropping systems suggests that farmers with scarce labor or capital would maximize returns by establishing timber-based agroforestry systems on their excess land. The application of a simple linear programming model developed for the optimal allocation of land to monocropping and tree intercropping considering farmers' resource constraints showed that cumulative additions of widely spaced tree hedgerows provides higher returns to land, and reduce the risk of agroforestry adoption by spreading over the years labor and capital investment costs and the economic benefits accruing to farmers from trees. Therefore, incremental planting of widely spaced tree hedgerows can make farm forestry more adoptable and thus benefit a larger number of resource-constrained farmers in their evolution towards more diverse and productive agroforestry systems.

Introduction

In the Philippines, timber tree planting on small upland farms has been promoted as a way to restore degraded lands and produce scarce tree products for household consumption. As natural forests continued to recede and timber demand and price increased, farm forestry emerged as a profitable farm enterprise. As a result tree planting spread all over the country and farm-grown timber trees became the source of raw materials, income, and employment for farmers and the local and national timber industry. Farmers' intensive tree establishment and management practices ensure tree survival and growth. However, the intimate association of fast-growing timber trees and crops on small farms severely reduces intercrop yields, thus decreasing net returns and increasing risks. Benefits from tree farming can be further reduced as farmers' management strategies to minimize tree-crop competition (e.g., severe pruning) adversely affect tree growth and timber quality. This study aims to document farmers' tree growing and management practices, to identify determinants of tree planting and constraints that limit farmers' potential to grow timber trees on farms, and to assess the profitability and adoptability of smallholder's timber production systems.

Methods

Various participatory research methods were used in this investigation including on-farm trials, farm and market surveys, multiple farm visits and focused group discussions. On-farm trials were conducted from September 1997 to January 2001 to assess the growth and economic performance of two popular fast-growing timber species, *Gmelina arborea* (gmelina) and *Eucalyptus deglupta* (bagras), in association with maize. Two tree-maize systems were tested, trees planted in blocks (woodlots) at close spacing (i.e., 2 x 2.5 m), and trees in hedgerows at wide spacing (i.e., 1 x 10 m). The performance of these tree-crop systems was compared to maize monocropping. The study was conducted in the upland municipality of Claveria, Misamis Oriental, Philippines, in the context of a research program by the World Agroforestry Center (ICRAF) to rehabilitate and improve utilization of degraded uplands, and in support of development activities, funded by the Spanish Agency for International Cooperation (AECI), aiming to scale-up agroforestry innovations in several upland municipalities of Mindanao and the Visayas.

Results and discussion

Farmers have accumulated wide knowledge about timber trees and how to cultivate them. They grow timber trees for various reasons: for household consumption of wood products (i.e., lumber and fuelwood); to accumulate capital and generate cash income; for environmental reasons, such as erosion control and soil fertility improvement; and for other benefits like boundary demarcation, shade and shelter. The study also suggests that younger farmers, with available draft animal labour, with scarce family labour, and actively involved in village-based organizations are the segment of the rural people most likely to adopt tree farming. Contrary to expectations, the study also found that owning larger farms (i.e., above the average size) and the availability of off-farm income are not major incentives to invest in timber tree farming. On the contrary, full-time farmers and owners of smaller landholdings are also active tree planters as demonstrated by highest timber tree densities found on the smaller farms (**Figure 1**).

The availability of off-farm income appears to be an incentive to less labour-demanding tree farming when the allocation of farm family labour to work off-farm limits investments on labour-demanding farm enterprises, such as annual cropping.

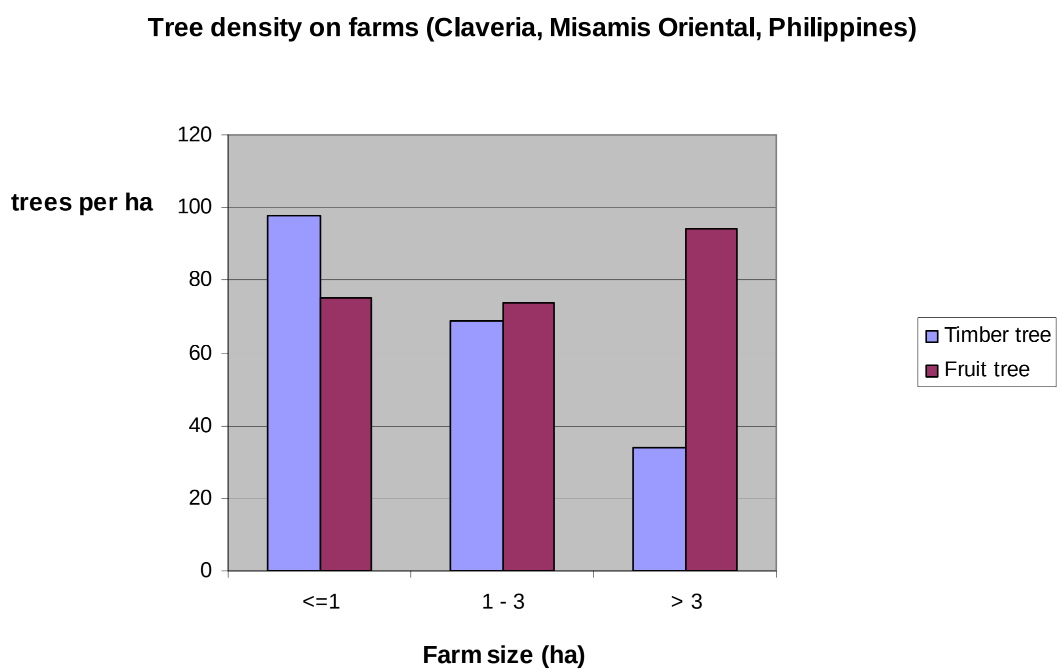

Figure 1: Higher timber tree density on small farms, Claveria, Misamis Oriental, Philippines

An initial survey among farmers in Claveria showed that lack of access to germplasm, tree-crop competition, poor management practices, low timber price, and policy disincentives to tree harvesting and marketing impede further development of timber-based agroforestry systems. In addition to these, tree planters and non-planters alike identified tree competition with field crops as the most important constraint to timber tree planting. Farmers have observed that crop yields can be severely reduced as far as five to seven meters from a row of fast-growing timber trees and reported short intercropping periods when trees are planted at close spacing. Nevertheless, tree-crop competition is not an impediment to tree farming and planters have developed methods to control and reduce it. Severing tree roots spreading into the cropped alley by ploughing close to tree rows, and frequent and severe branch pruning are commonly practiced to reduce below- and above-ground competition and thus prolong the period of intercropping. However, previous research and tree growers themselves recognized that tree root and branch pruning are detrimental to tree growth. They are also uncertain whether intercrop yield increases can compensate reduced tree growth and increased labour costs of heavy pruning.

Farmers suggestions, supported by field observations of the increasingly popular practice of planting trees on contour grass strips 6 to 8 m apart, led us to hypothesize that planting tree lines at wider distance is another option that will provide higher economic returns because: (a) crops can be planted in the alleys between rows of trees for longer period; (b) trees will grow faster because of the more intensive management and favourable light regime; and (c) farmers would benefit from the reduction of area lost to trees and lower tree establishment and management costs. However, even if planted 10 m apart, gmelina proved to be very competitive, reducing maize grain yields below the break-even after the third cropping season. Bagras, however, allowed for six maize crops above the break-even yield. It is, therefore, more appropriate than gmelina for intercropping systems. By the seventh cropping season, gmelina had reduced maize grain yields by 60% and bagras by 40% (**Figures 2 and 3**). These results led us to conclude that if mixed agroforestry systems with fast-growing timber trees and sun-demanding crops are to produce acceptable levels of intercrop yields (assuming a threshold of 20% crop yield reduction), tree basal areas should be within the range of 2 to 4 m^2 ha^{-1}. This is equivalent to a density of 41 to 81 trees ha^{-1} (spacing of 10 x 25 and 5 x 25 m) when average dbh is 25 cm or a final crop of 28 to 57 trees ha^{-1} if trees are harvested when dbh is 30 cm. For higher tree densities and if crop production is a priority, fast-growing trees should be planted in other farm niches away from crops, such as home gardens, farm boundaries, or fallows, rather than on cultivated land.

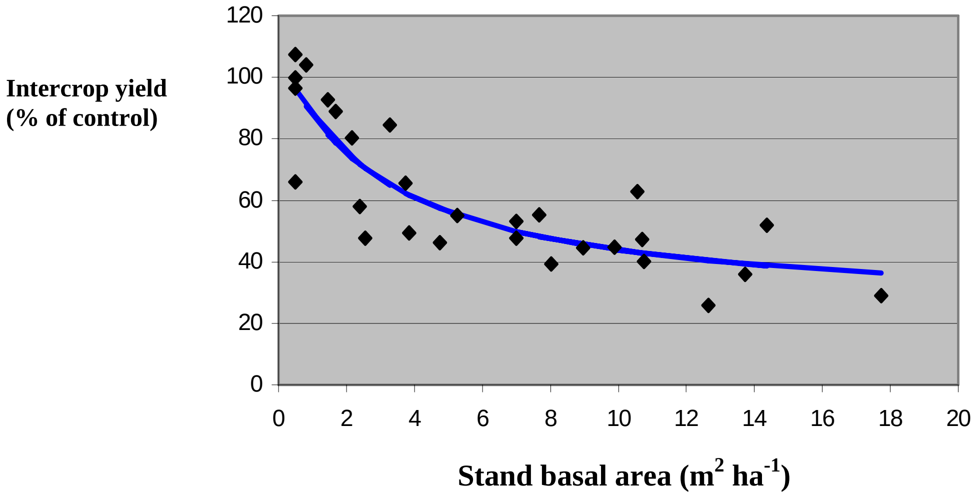

Figure 2: Maize grain yield decline as stand basal area of *Gmelina arborea* increases.

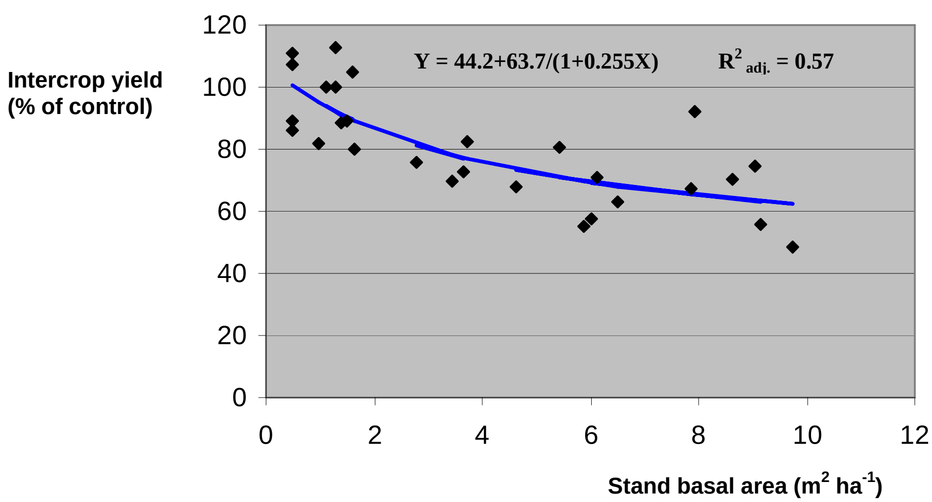

Figure 3: Maize grain yield decline as stand basal area of *Eucalyptus deglupta* increases.

We confirmed the hypothesis, however, that trees grow faster in widely-spaced tree hedgerows than in blocks **Table 1**. With frequent but moderate pruning and intensive management of alley crops, data on tree growth collected during a four-year period indicated that if planted in hedgerows gmelina would produce in 8 years volumes of timber ranging from 69 to 110 m^3 ha^{-1}, and bagras would produce 146 to 185 m^3 ha^{-1} in rotations of 12 years. Planting trees in widely-spaced hedgerows is, therefore, appropriate for timber production in agroforestry systems.

Table 1: Increased dbh growth with age of *Gmelina arborea* planted in hedgerow as compared with block planting.

	17 mo		34 mo		54 mo	
Tree arrangement	N	dbh (cm)	N	dbh (cm)	N	dbh (cm)
Hedgerows (1 x 10m)	147	5.0	74	14.1	65	19.9
Blocks (2 x 2,5 m)	156	5.7	86	12.7	70	17.1
SED		0.36		0.43		0.72
F-test probability		0.146		0.052		0.028

N: total number of trees (excluding border trees)

SED and p-values have been correctly calculated based on plot averages, not individual tree values

If the current low price of farm-grown timber prevails and with timber yields in the lower range of those estimated, maize monocropping is more profitable than maize-timber intercropping (Table 2). Only in the event of a timber price increase (of Ph P 1 $bdft^{-1}$ for gmelina and Ph P 4 $bdft^{-1}$ for bagras) and high timber yields, the profitability of timber intercropping would be similar or higher than that of maize monocropping at a 20% discount rate (Figure 4). Given that nowadays large stocks of small-size timber of low to average quality exist on farms and the limited demand for this type of timber, to improve the financial returns of farm forestry in the Philippines it would be imperative for tree farmers: i) to diversify tree production by planting timber species that command higher market price. Several options are already available, or becoming more available to farmers, such as *Swietenia macrophylla* (mahogany) or bagras; ii) to grow larger trees and of higher quality intended for high-value timber products like for example, veneer. The on-farm trials conducted in this study showed that it is possible to produce in intercropping systems with widely-spaced tree hedgerows logs with the size and form required by the wood industry. Tree hedgerow systems proved to be financially superior than the commonly promoted tree blocks because of the lower establishment and management costs, higher maize yields produced (confirmed only in the case of bagras), and higher timber yields (confirmed for gmelina and probably for bagras).

Timber-based agroforestry systems are, however, superior to monocropping in terms of returns to labour invested. Therefore, they are the best option for labour-constrained farmers aiming to maximize land productivity with scarce labour. Timber intercropping would also turn out more financially attractive than monocropping in the event of moderate increases of farm labour wage. In the Philippines, this is likely to occur in the near future, as the economy diversifies and more rural people find work off-farm.

Table 2: Returns to land (Net present value, NPV) and returns to labour of agroforestry with *Gmelina arborea* and maize monocropping over an 8-year tree rotation period.

System	Maize (t/ha/9 yr)	Timber (m^3 ha^{-1})	Returns to land: NPV (US$ ha^{-1})		Returns to labour: net returns (US$ work-day^{-1})	
			dr = 15%	dr = 20%	dr = 15%	dr = 20%
Maize monocropping	70.1	0.0	1,596	1,348	3.8	3.8
Low timber yield						
Tree hedgerow (1 x 10 m)	12.5	69.1	1,131	852	5.7	4.9
Tree block (2 x 2.5 m)	12.9	60.8	1,040	793	4.6	4.0
High timber yield						
Tree hedgerow (1 x 10 m)	12.5	110.6	1,631	1,192	7.4	6.2
Tree block (2 x 2.5 m)	12.9	104.4	1,564	1,151	6.0	5.1

Timber price = PhP 4 bd ft^{-1} or US$ 42.4 m^3

Exchange rate for 1998: US $ = PhP 40 (data from: exchange rate_1990-2002 www.bsp.gov.ph/statistics/exrate/usd/year_htm)

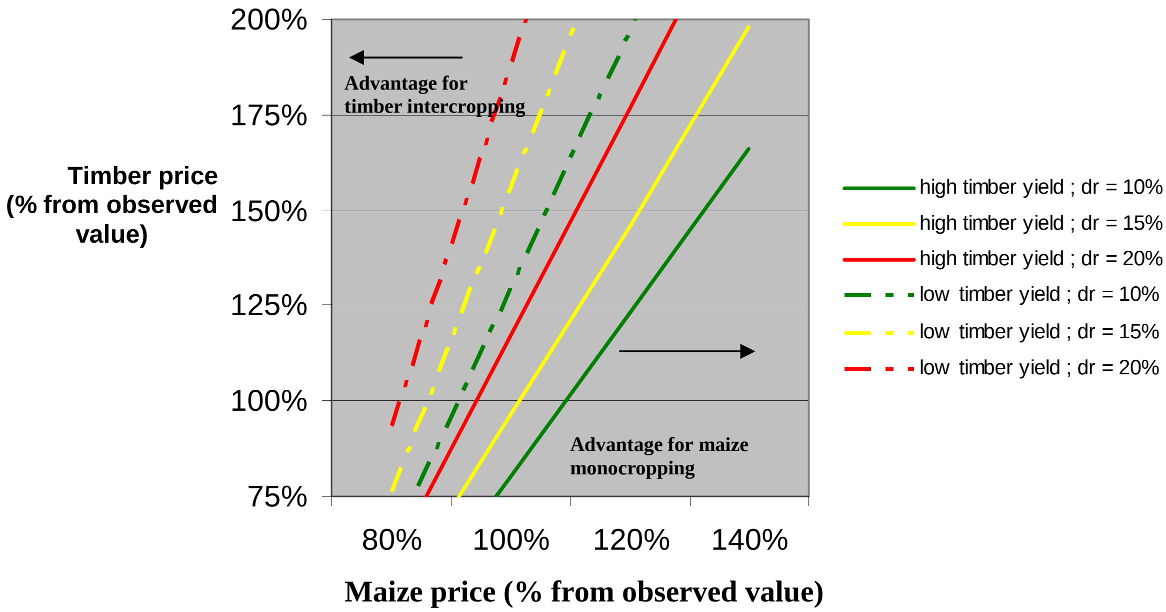

Figure 4: Break-even line of NPVs of maize monocropping and *Gmelina arborea* intercropping (observed labour cost)

Farmers' evaluation of timber production systems broadly pointed to the need, in smallholder farm forestry, of segregating timber from crop production enterprises. Because of tree-crop competition, they preferred systems in which the tree-crop interface is minimal, such as line plantings (i.e., trees on boundaries or widely-spaced hedgerows) or small-scale woodlots away from crops.

A linear programming model developed for the optimal allocation of land to monocropping and tree intercropping that maximizes the net present value (NPV) of these farm enterprises over an infinite time horizon and satisfies farmers' labor constraints and regular income requirements (see Annex 1) showed that incremental planting or cumulative additions of tree hedgerows is an intermediate option in which trees and crops can be temporarily combined into the same land unit to maximize farmers' benefits and produce timber in a commercial scale without compromising food crop production. This tree farming system, also called rotational timber fallows, is more "acceptable" to farmers (i.e., more profitable and feasible, less risky and compatible with farmers' values and farmers' valuation of benefits) because it provides higher returns to land and reduce the risk of agroforestry adoption by spreading over the years labor and capital investment costs and the economic benefits accruing to farmers from trees (**Tables 3 and 4**). We, therefore, propose the gradual planting of tree hedgerows as a strategy that will enhance adoption of tree-based farming systems among smallholder farmers.

Table 3: Optimal land allocation to maize monocropping and timber intercropping by incremental tree planting.

Year	Area planted to		
	Maize monocropping (x_{i1}) (ha)	Tree intercropping (x_{i2}) (ha)	Unused (fallow) (ha)
1	1.16	0.43	0.91
2	1.11	0.26	0.7
3	1.33	0.12	0.35
4	1.59	0.00	0.095
5	1.62	0.04	0.018
6	1.59	0.05	0.0
7	1.55	0.04	0.0
8	1.10	0.44	0.0
9	1.10	0.00	0.0
10	1.10	0.00	0.0
11- ∞	1.10	1.40	0.0

Table 4: Increased land productivity and income, and reduced labour use by adoption of rotational timber fallow systems.

Year	Amounts unused		Surplus
	Land (unproductive fallow) (ha)	Labor (wd yr^{-1})	Income (Ph P yr^{-1})
1	0.91	0.0	4,854.1
2	0.7	0.0	6,081.2
3	0.35	0.0	6,074.8
4	0.095	0.0	7,737.1
5	0.018	0.0	7,808.3
6	0.0	0.0	7,800.6
7	0.0	8.6	6,597.2

8	0.0	0.4	4,407.3
9	0.0	56	50,413.3
10	0.0	0.0	34,063.3
11	0.0	0.0	20,058.6
12	0.0	40	0.0
13	0.0	84	0.0
14	0.0	92	0.0
15	0.0	86	0.0
16	0.0	87	46,874.0
17	0.0	0.4	4,407.3
18	0.0	56	50,413.3

The sizeable marketable surplus of fast-growing timber trees generated in small upland farms and the large number of viable farm forestry industries that have emerged in the region as a result, evidence the success of smallholder farmers as timber producers. Farm-grown timber is increasing its share of the wood used and traded in the local, national and even international markets. However, current produce is not a practical substitute for timber products requiring large diameter and quality logs. Therefore, wood processors in the Philippines are still largely dependent on imported timber to meet increasing domestic demand. The wood industry is realizing that farm forestry has the potential to contribute to import replacement but several constraints remains that limit further development of the wood industry based on locally produced farm-grown timber. The Philippine government should remove policy restrictions curtailing the use of planted trees and provide incentives appropriate to smallholder farmers. On the side of the tree farmers, the challenge is to increase production and quality of a variety of timber species. Only by targeting those segments of the wood industry that demand quality timber, would farmers be able to seize the economic opportunity of farm forestry.

Conclusions and recommendations

This research provided insights on how farmers grow timber trees; it quantified the biophysical performance and profitability of timber production systems, and took into consideration farmers' practical knowledge and perceptions for the design of adoptable tree farming systems. The findings reported in this study also highlight the need of farm forestry extension programs to address three broader issues. First, the lack of quality germplasm of a wider list of timber tree species suited to the diverse environmental and socio-economic conditions of upland farmers. If germplasm is made available, smallholder farmers have already proven to be active and successful tree growers. Secondly, there is a need to demonstrate to farmers the advantages of using quality germplasm and improved tree management practices (e.g., pruning and thinning). A combination of on-farm trials, with active involvement of farmers in design and management, and more training can address this. Thirdly, extension and dissemination methods need to be improved, with a focus on facilitating a gradual transition towards agroforestry instead of planning and promoting standard tree planting packages. And lastly, there is an urgent need of dialog with government agencies to lift existing policy regulations that prevent the establishment and use of tree resources on farms.

Annex 1:

Linear programming techniques were used to develop a model that will determine the "optimal" combination of intercropping and monocropping systems that maximizes the net present value (NPV) over an infinite time horizon while considering simultaneously farmers' labour constraints and minimum yearly income requirement. The model assigns each year throughout the planning horizon (i.e., the time period necessary to achieve the optimal combination of the monocropping and intercropping systems that will be maintained in perpetuity) a portion of the farm to monocropping and tree intercropping systems. Then for demonstration purposes, the model is applied to the case of an average smallholder farmer in Claveria. The farmer wants to estimate the area that should be devoted each year to gmelina timber production and to maize monocropping while maximizing returns to land over an infinite time horizon with his limited land, labour and capital resources. Based on the results of the financial analysis and farmers' evaluation of timber production systems (Chapter 4.2), we identified widely-spaced tree hedgerows as the best tree-maize combination for small-scale farm forestry.

In the application of the model, the NPV values of the objective function were calculated for an infinite number of rotations of both monocropping and tree intercropping systems. This NPV, which corresponds in forest economics to the classic 'Faustmann principle', is commonly called 'land value' or 'soil value' as it implicitly considers the opportunity cost of land [Romero, 1994]. Data on tree growth and maize yield used in the calculation of the NPV was collected from on-farm experimental plots established to study maize-timber tree intercropping systems. Further details on plot size and management, maize grain and timber yields are given on Chapter 4.1 and 4.2. It was assumed that trees are planted right before sowing the dry season crop of maize (September) and harvested once the rotation period is completed. The optimal rotation of gmelina was considered to be 8 years. The annual discount rate of 15% was selected for the calculation of the NPV of maize monocropping and tree-maize intercropping enterprises. This rate was assumed to approximately represent the rate farmers from Claveria use to discount future benefits considering the cost of borrowed capital in the area. Finally, we used the computer program LINDO (LINDO Systems Inc., 1998) to solve the problem.

The following notation is used in the formulation of the model:

Constants:

r = tree rotation period (years)

npv_{ij} = net present value per hectare of system j in year i

A = farm size (hectares)

l^1 = annual labour requirements per hectare of monocropping

l_t^2 = annual labour requirements per hectare of tree intercropping in year *t* of rotation period

wd = annual available work days

m^1 = net margin per hectare of monocropping

m_t^2 = net margin per hectare of tree intercropping in year *t* of rotation period

I = annual income requirements

Decision variables:

x_{ij} = area (hectares) of system *j* planted in year *i*

Other variables:

M_{r+2} = area (hectares) allocated to monocropping in perpetuity from year r+2 on

TM_{r+2} = area (hectares) allocated to tree intercropping in perpetuity from year r+2 on

F_{r+2} = fallow area from year r+2 on

Assuming two possible production systems: *j* = 1 denotes monocropping system and *j* = 2 denotes tree intercropping system, the whole structure of the model reads as follows:

Objective function:

$$Max \quad \sum_{i=1}^{r+2}\sum_{j=1}^{2} npv_{ij}\, x_{ij} \qquad (1)$$

subject to

- *land constraints*:

$$x_{i1} + \sum_{k=1}^{i} x_{k2} \leq \mathrm{A} \qquad i = 1, 2, ..., r+2 \qquad (2)$$

- *labor force constraints*:

$$l^1 x_{i1} + \sum_{k=1}^{i} l^2_{i-k+1} x_{k2} \leq wd \qquad i = 1, 2, ..., r+1 \qquad (3.1)$$

$$l^1 x_{r+2,1} + \sum_{k=1}^{i-(r+1)} l^2_k x_{i-k-r,2} + \sum_{k=i-r}^{r+1} l^2_k x_{i-k+1,2} + l^2_{i-(r+1)} x_{r+2,2} \leq wd \qquad r+1 < i \leq 2(r+1) \qquad (3.2)$$

- *family consumption constraints*:

$$m^1 x_{i1} + \sum_{k=1}^{i} m^2_{i-k+1} x_{k2} \geq I \qquad i = 1, 2, ..., r+1 \qquad (4.1)$$

$$m^1 x_{r+2,1} + \sum_{k=1}^{i-(r+1)} m^2_k x_{i-k-r,2} + \sum_{k=i-r}^{r+1} m^2_k x_{i-k+1,2} + m^2_{i-(r+1)} x_{r+2,2} \geq I \qquad r+1 < i \leq 2(r+1) \qquad (4.2)$$

- *accounting rows*:

$$M_{r+2} = x_{r+2,1}$$

$$TM_{r+2} = \sum_{i=1}^{r+2} x_{i2} \qquad (5)$$

$$F_{r+2} = 2.5 - x_{r+2,1} - \sum_{i=1}^{r+2} x_{i2}$$

- decision variables domain constraints:

$$x_{ij} \geq 0 \qquad \forall i, j \qquad (6)$$

As the series of net incomes are assumed to continue indefinitely for an infinite number of periods, the coefficients npv_{ij} corresponding to variables x_{i2} are the net present values calculated over an infinite rotation period. For variables x_{i1}, only the *npv* attached to $x_{10,1}$ has been calculated in perpetuity.

Constraints (2) guarantee that the total area allocated any year to both production systems does not exceed the total farm area. Index *i* varies from 1 to *r*+2 (i.e., planning horizon) because the farmer will need r+2 years to establish the optimal combination of monocropping and intercropping systems. From year *r*+2 on, the farm area allocated to system 1 and 2 would be maintained unchanged in perpetuity.

Constraints (3.1) and (3.2) secure that the farm labor used in any year to both production systems is not higher than the available family labor. Block (3.1) forces the solution to satisfy the labor force constraint for the first r+1 years of the planning horizon, as the area allocated to tree intercropping gradually increases until a complete series of units containing trees of all the individual ages within the rotation period is established. Block (3.2) forces the fulfillment of the labor force constraint from year *r*+1 to year 2(*r*+1), when "intercropping" units with trees of all individual ages exist simultaneously. Similarly, block (4.1) imposes the solution to satisfy annual income demands for the first r+1 years, and block (4.2) from year *r*+1 to year 2(*r*+1).

Accounting rows have been added just to easily quantify the total final area allocated to each system at the end of the planning horizon. Constraints (6) simply ensure non-negativity for all decision variables.