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To plant or not to plant – developing a model to analyse rural households' tree planting behaviour

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Abstract

This paper deals with rural households' decision regarding tree planting on farmland in developing countries. This has been the topic of numerous descriptive socio-economic studies. In many cases the findings and claims of these studies are ambiguous, although there is a general agreement about the importance of imperfect markets. In addition, no studies that we know of have formalised the tree planting decision in a prescriptive format. In this paper we develop and evaluate a predictive theoretical rational-behaviour model to explore the tree planting decision that encompasses household factor endowments and market characteristics. We elaborate upon the model characteristics and discuss the strengths and weaknesses of the model. In addition, we assess the data needs for the model and the data availability in a Tanzanian context.

Key words: decision model, labour-land ratio, trees outside forest, trees on farmland

Introduction

Ever since the early concerns of environmental degradation following population growth in developing countries, policies and measures to promote tree planting have been part of donor strategies. The integration of trees on private farmland is recognised as a means for improving farmers' livelihoods in areas facing increasing scarcity of forest products. Accordingly, rural households' decision to plant trees has been studied intensively with regard to purposes of tree planting and constraints and opportunities to enhance tree planting. The studies have found that the roles and functions of trees and purposes of tree planting are manifold. Trees may serve to improve crop yields in agriculture (Franzel 1999), alleviate risk through livelihood diversification (Patel *et al.* 1995), function as a capital asset (Dewees and Saxena 1995), alleviate labour requirements in woodfuel collection (Aalbæk 2001), provide fodder for livestock (Hoekstra 1994), improve health through diversification of the diet (Warner 1993), and provide a number of intangible services, such as shade, improvement of microclimate, and erosion control. With regard to opportunities and constraints for enhancing farmers' tree planting the studies emphasise land scarcity (Warner 1993), insecurity of land tenure (Gausset *et al.,* in prep.), adverse climatic conditions (Nyadzi *et al.* 2003), high time preference rates of farmers, poor access to germplasm (Aalbæk, 2001), and the presence of cattle (Warner 1993) as constraining factors, while factors conducive for tree planting are wood scarcity (Patel *et al.* 1995), labour scarcity (Dewees and Saxena 1995), lack of capital to invest in cash crops and paid labour (*ibid.*), and high population density (Patel *et al.* 1995). The effect of access to markets for wood products is ambiguous (Warner 1993, Aalbæk 2001) and some studies argue that insecurity of land tenure is less of a constraining factor in Africa than elsewhere (Warner 1993, Meijerink 1997).

The overall picture obtained from the literature is that the tree planting decision is very complex. Most studies on tree planting are descriptive, and the decision-making process of farmers with regard to tree planting remains thus to be described and analysed in a prescriptive format. Although many of the factors acknowledged to influence the tree planting behaviour of rural households cannot easily be included in a deterministic economic model, we find it useful within such a framework to seek a better understanding of the conditions under which tree planting may be a viable land use alternative. The opportunities

and constraints to farmers' tree planting can be grouped in those directly related to the household and those external to the household. Thus, tree planting behaviour is influenced by household preferences and endowments of capital, land and labour in combination with the availability, productivity, and markets for tree products, land, and labour.

The land and labour endowments of a household develops from the time of establishment by a young couple over the period of raising children to the stage where these children either (i) to an increasing degree take over the farm production functions or (ii) establish their own farm or migrate to town leaving the handling of the farm to their elderly parents. When ageing households face declining labour-land ratios surplus land can be sold, rented out, lent to somebody or left unutilised for re-growth of secondary forest. Tree planting may be a fifth and economically superior option. The demographic development of the household is influenced by a number of factors. At the regional level, migration from rural to urban areas leads to labour deficits and a declining area in agricultural production in certain rural areas. In such areas, plantation activities on surplus farmland may yield a higher return to labour and comprise a means by which the remaining population (often dominated by women and children) can enhance their livelihoods. A prescriptive model of households' tree planting behaviour should be able to encompass such aspects. In this paper, we seek to develop such a model.

The model
Our model describes the household from the time of establishment by a young couple, t_0, to the time when the household is dissolved and the children take over the possessions of their parents, T.

Objective function
The objective of the household is to maximise the net present value of the sum of income, I, obtained during the lifetime of the household and the realisation value, R, of the household's assets at time T. The household obtains income by selling firewood from either plantation, I_p, or the forest, I_f, through agriculture, I_a, and by selling land, I_l, and labour, I_w, as well as by withdrawing part of previous years' own savings, I_s. The household's assets comprise the value of agricultural land, plantations and savings, S. Thus, the household's problem can be expressed as:

$$\max\{I+R\} = \max\left\{\sum_{t=t_0}^{T} \frac{I_p(t)+I_f(t)+I_a(t)+I_l(t)+I_w(t)+I_s(t)}{(1+r)^t} + \frac{R_a(T)+R_p(T)+S(T)}{(1+r)^T}\right\} \qquad (1)$$

Households allocate land, labour and cash from own savings to earn income from the above activities. Land is accumulated either through clearing, L_c, or buying, L_b, and households may sell, L_s, land at will. Equation 2 shows that land in agriculture, L_a, equals the sum of net land accumulation and the initial land endowment, L_0, (land inherited) minus land occupied in plantations, which equals the area of plantation established, L_{pe}, within the period $t-n$ to t, where n denotes the rotation time of the plantation. It follows from this that land in plantation is automatically released to agricultural production in the year following clearing of the trees.

$$L_a(t) = \sum_{\tau=t_0}^{t-1} \left(L_c(\tau) + L_b(\tau) - L_s(\tau) \right) + L_0 - \sum_{\tau=t-n}^{t} L_{pe}(\tau), \quad t_0 \leq t \leq T \qquad (2)$$

Equation 3 shows that households can accumulate savings that will earn an interest and from which they can withdraw to pay cash expenses. Thus, we define savings as an interest bearing investment, such as livestock or other businesses.

$$S(t) = S(t-1)(1+r) - I_s(t), \quad t_0 \leq t \leq T \qquad (3)$$

where $S(t_0 - 1) = S_0$ is inherited.

Constraints
Households use their own or bought labour as input in production, and may sell their labour. With regard to income generating activities, we distinguish between two seasons, namely dry, d, and rainy, r. Thus, agriculture and plantation establishment can only be done in the rainy season, while the other activities can be performed in both seasons. We have exogenously defined a household demographic typology according to which the labour endowment of the household, w_h, develops over time. α_r denotes the share of the labour endowment available in the rainy season. Households use their own labour endowment or bought labour, w_b, as input to clearing of land, w_c, agriculture, w_a, forest work, w_f, plantation establishment, w_{pe}, and tending, w_p, and for earning income as casual labour, w_s. Thus, the labour constraints are:

$$w_a(t) + w_{pe}(t) + w_{cr}(t) + w_{fr}(t) + w_{pr}(t) + w_{sr}(t) - w_{br}(t) \leq \alpha_r w_h(t), \quad t_0 \leq t \leq T$$
$$w_{cd}(t) + w_{fd}(t) + w_{pd}(t) + w_{sd}(t) - w_{bd}(t) \leq (1 - \alpha_r) w_h(t), \qquad t_0 \leq t \leq T$$

To simulate food security concerns, we have included a minimum household agricultural income, $I_{a,\min}$, that is related to the household demographic typology. To describe the poorly functioning capital markets we have introduced a requirement for households that engage in activities involving cash expenses, such as tree planting or buying of land and labour, that they can pay all these costs, $C(t)$, from their accumulated savings from the previous years. To reflect the need for firewood we have included a minimum firewood consumption, $F_{\min}$, that the households must reach either from harvesting in their own plantation, F_p, the forest, F_f, or through buying firewood, F_b. Households may sell any firewood, F_s, in excess of the minimum consumption. Thus, the model has the following constraints:

$$I_a(t) \geq I_{a,\min}(t), \qquad\qquad t_0 \leq t \leq T$$
$$F_p(t) + F_f(t) + F_b(t) - F_s(t) \geq F_{\min}(t), \quad t_0 \leq t \leq T$$
$$S(t-1) \geq C(t), \qquad\qquad t_0 \leq t \leq T$$

In addition to the mentioned constraints, non-negativity constraints are included for income, savings, firewood extraction, land and labour. Geographical variation is introduced through differentiated prices on land, labour, and firewood as well as differentiated yields in agriculture and plantation. With regard to this a major practical constraint is the rather large amounts of data needed for parameter estimation. In the following section we present an approach to estimation of model parameters based on data from Tanzania.

The case of Tanzania

We have compiled data from Tanzania for estimation of parameters. The main reasons for choosing Tanzania were relevance and data availability. With regard to relevance, the government of Tanzania strongly encourages tree planting in rural areas to alleviate problems associated with lack of forest resources. With regard to data, we have the privilege of disposing over a unique set of data on tree planting behaviour covering more than 1,500 households in 32 districts of Tanzania (Aalbæk 2001). Under this implementation strategy, we have sought to estimate parameters to provide for district-level variation in agricultural yields and village-level variation in labour requirements to gather firewood from forests. Table 1 displays the different data sources used to compile the parameter estimates for the model in a Tanzanian context.

Table 1: Approaches and data sources for parameter estimates

Parameter	Estimation approach and data sources
Household demographic typology	Regression of household endowments of adult equivalent units (AEUs) on household head age using detailed data on household composition in terms of age and gender and AEU factors from the literature.
	Source: Cavendish 2002:56, National Bureau of Statistics 2002, Own survey from Iringa District, Tanzania
Agricultural yield and labour requirements	Agricultural yields from three main crops in the season 1998/99 at the district level and prices on agricultural crops from seasons 1992-1999 at regional markets. Agricultural labour requirements from the literature.
	Source: Ministry of Agriculture and Food Security 2000, 2005, Ramadhani *et al.* 2002, Alwang and Siegel 1999:1465.
Forest yield and labour requirements	Village means of households' reported walking distance to area of firewood collection combined with own survey of headload weights and conversion factors from the literature.
	Source: Hofstad 1997:23, Aalbæk 2001, Own survey from Iringa District, Tanzania.
Plantation yield and cash and labour requirements	Plantation yield from an on-farm study of woodlot establishment of *Acacia crassicarpa* from Tabora District.
	Source: Ramadhani *et al.* 2002.
Household minimum agricultural income	Constant across the country based on the household demographic typology and estimates of minimum consumption in the literature.
	Source: Alwang and Siegel 1999:1464, modified.
Household minimum firewood consumption	Constant across the country based on the household demographic typology and estimates of minimum consumption in the literature.
	Source: Luoga *et al.* 2000:248, modified, Matthews 2001:211.
Household labour endowments	Constant across the country based on household composition and estimates of labour equivalents from the literature.
	Source: Byingiro and Reardon 1996:130.
Labour requirement to clear land	Constant value based on a survey by the corresponding author.
	Source: Own survey from Iringa District, Tanzania.
Land and labour prices	Constant across the country based on the corresponding author's own research.
	Source: Own survey from Iringa District, Tanzania.
Interest rate	Based on observations in the literature.

	Source: Patel *et al.* 1995:520 (12,5% Kenya), Ramadhani *et al.* 2002 (20% Tanzania).
Observed tree planting behaviour	Observed tree planting behaviour for more than 1,500 households in 32 districts of Tanzania.
	Source: Aalbæk 2001.

It is seen from Table 1 that most of the parameter estimates are based upon empirical data from Tanzania. We have formed the household typology on the basis of data on household composition from Iringa District, Tanzania. Geographical variation in agricultural yield has been estimated from district-level data on yields for the agricultural season 1998/99. Data to describe the geographical variability of yields in plantations and prices on labour and land have been difficult to obtain. Accordingly, yield in plantations has been estimated from a study in Tabora District, and is thus constant for all areas of Tanzania in the model. Likewise, prices on labour and land have been estimated from own research efforts and are also constant in the model. Most of the other parameters have been estimated from published research.

Discussion

Having presented the model and data issues with regard to implementation in Tanzania we now turn to a discussion of the strengths and weaknesses of the model.

We set out to compile a predictive model to explore the tree planting decision by rural households in developing countries. The resulting model enables us to analyse the impact of factor availability, market failures, and geographical differences of relevance to the tree planting decision. We thus believe that the model has the necessary characteristics and elements to serve the purpose. Having said this, there are numerous weaknesses to the model. First of all, it does not include feedback relations, such as income saturation (we implicitly operate with a linear utility function) and increasing scarcity of factors, e.g. rising/falling prices on land and labour caused by rising/falling population density. Another relevant opportunity for improving the model would be estimates of development in soil productivity over time after clearing. Undoubtedly, this factor influences the choices and practices of farmers with regard to land use. Furthermore, using a fixed household demographic typology is a strong simplification. Variation in family structure between geographical areas and variations between households in household composition will assert great influence on the labour and consumption variables for which the household demographic typology forms the basis. In addition, our typology is formed by a regression using static data, which implies that we assume no changes over time in the conditions influencing household demographics, which, of course, is a rather unrealistic assumption. A third and related aspect is that the model does not include geographical differences in population density and development. In the current model, this aspect must be included indirectly through differences with regard to prices on land and labour. Fourth, our model is strictly deterministic, which precludes us from including the important aspects of risk and portfolio considerations in the choice of land use. Finally, the fact that we have specified a household production function implies that intra-household issues such as gender cannot be analysed in the model framework. Then, of course, there are numerous non-economic factors which cannot easily be incorporated in an economic model, such as land tenure issues, rules regulating livestock movements etc.

A major constraint to the implementation is the scarcity of reliable data. The use of regional statistics on agriculture yields based on only one season necessitated some censoring of the data, but even after this process the reliability remains questionable. Tanzanian districts are rather large units within which there exists considerable variation in biophysical variables of importance for agricultural yields. An alternative approach to stratifying the areas within Tanzania with regard to agricultural yields is to base the stratification upon agro-ecological

zones. Such an agro-ecological stratification was done by Aalbæk (2001) based upon, among others, Greenway (1973). Another weakness in the data is the lack of variability in the yields of plantations. Currently, plantations in all areas yield the same volumes that are based on a study from Tabora district (Ramadhani *et al.* 2002). There are, however, a number of other studies on yields in farmers' plantation (Okorio and Maghembe 1994, Karachi *et al.* 1997, Nyadzi *et al.* 2003) in Tanzania, but we have, so far, not been able to find enough studies to model geographical variation within the country.

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