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Decision Modelling for the Integration of Woody Plants in Smallholder Farms in the Central Highlands of Ethiopia

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Abstract

Farmers' perceptions of the utility and the constraints of locally available woody species are assumed to influence the decision-making and the behaviour of tree and shrub integration into current land-use types. Accordingly, the objectives of this study are (1) to analyse farmers' decisions in making use of woody plants under perceived constraints and (2) to analyse influencing factors that determine the deliberate tree and shrub growing behaviour.

The methodology bases on the approaches of the 'Farming Systems' and the 'Behavioural Decision-Making'. Influence diagrams are constructed incorporating the perceived utility and decision determinants of deliberately grown woody plants. Modelling of the tree adoption behaviour of farmers employs the 'Discriminant Analytical Approach' taking into account the identified external and internal influencing factors.

Results from the decision modelling reveal that woody plants are grown on-farm in view of the perceived utility of the species, predominantly fuelwood and timber-based produce, followed by cash-generation. Service functions pertaining to the protection of land gain secondary importance to the tree produce. Major decision determinants comprise resource-based factors, e.g. the shortage of land and seedlings or competition with agricultural crops, over stochastic-environmental factors. Results of the 'Discriminant Analysis' confirm that the adoption of trees is characterised by the available resource base, the access to infrastructure and support services as well as by personal characteristics of the farmers.

Keywords: farming systems, behavioural decision-making, discriminant analysis, land-use pattern, non-competitive tree growing, agroforestry

1 Introduction

In Ethiopia, about 90% of the total population directly depend on agriculture and live in rural areas. The land use policy as pursued since about 30 years has led to the expansion of the agriculturally used land area. This has preferably been at the expense of forested

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land. The depletion of still remaining forests has been caused by cutting trees, gathering tree produce, grazing animals, etc. which are common livelihood activities of the rural people.

The advancement in deliberate management of trees and shrubs outside the state forest reserves has remained below expectation. Research works on tree-based land use practices have mainly focussed on production technologies. Less is known about the factors which influence farmers' decisions on tree and shrub growing, their perceived utility and preferred woody species. This is to assume that decision-making processes of small farmers in Ethiopia have not been studied sufficiently yet.

Participatory approaches to understand local people's needs, perceptions, and objectives as well as to build on local knowledge and experience for decision-making are assessed undeniable for the successful integration of woody plants on-farm. Accordingly, the objectives of the study are (1) to shed light on smallholders' decision-making with the focus on their perceptions to better understand farming constraints and utility of decision outcomes; (2) to embed this investigation into tree adoption studies to cross-check farmers' perceptions as decision determinants.

2 The Study Area

Arrangements had been made to carry out the study near the Holetta Agricultural Research Centre (HARC) in the Central Highlands. The criteria for selection of the particular locations were (1) the Agro-Ecological Zone (AEZ) and (2) the access to a paved road network to contrast between the villages as well as to identify differences between tree growers and non-growers. Assumed differences in tree resources endowment made a critical criterion for the selection of two villages in different AEZs (MOA, 2000). The study sites were selected in Dendi and Ejere districts. The villages under study were assigned to M 2-5 "Tepid to cool moist mountains and platea" and M 3-7 "Cold to very cold moist mountains" respectively.

3 How to Approach Farmer's Decision Making and Behaviour

3.1 The Farming Systems Approach (FSA)

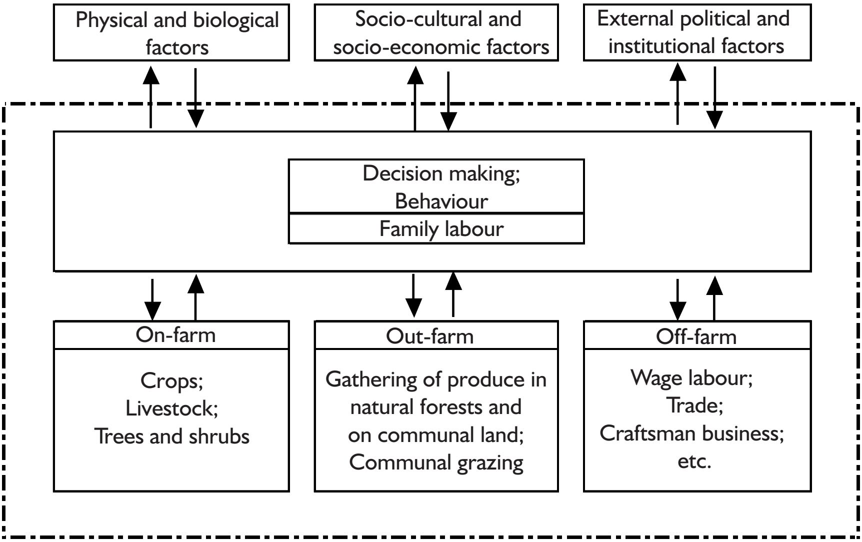
According to (Beets, 1990, p.725) a farm system "is a unit consisting of a human group (household) and the resources it manages in its environment" (Beets, 1990, p.163) (Figure 1).

The FSA is appropriate to embed the farmers' decision-making and behaviour into the frame of influencing factors. It centres the farm household system as the basic unit of assessment (Beets, 1990, p.727).

3.2 The Decision-Making Approach

The Decision Theory is based on the assumption that each choice or decision entails consequences (called 'outcomes') and that each of the actors making the decisions has preferences for the different outcomes (Gladwin, 1989; Barlett, 1980). The Descriptive or Behavioural Decision-Making Approach focuses on decisions incorporating

Figure 1: Basic model of the farm system of a farmer's household

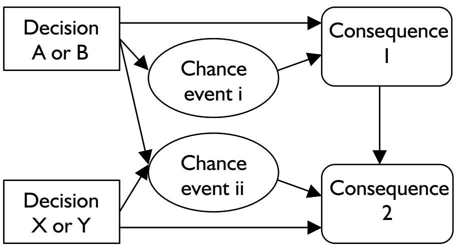


Source: modified from (Beets, 1990, p.163)

alternatives that people actually take. It has been proven that the Behavioural Decision-Making Approach is highly suitable to actors in an agricultural surrounding and to address decision-making constraints (Barlett, 1980; Gladwin, 1989; Negussie, 2003). Influence diagrams are notably simple visual representations of a decision problem and reflect a snapshot of the perception in a decision situation (Figure 2).

The relationships among decision alternatives ('decision node'), uncertain events ('chance node'), and consequences ('consequence node') are common elements depicted in rectangular boxes with sharp edges, elliptical circles, and rectangular boxes with smoothed edges shapes respectively (Barlett, 1980; Gladwin, 1989; Franzel *et al.*, 1996; Lindley, 2003).

Figure 2: Concept of an influence diagram



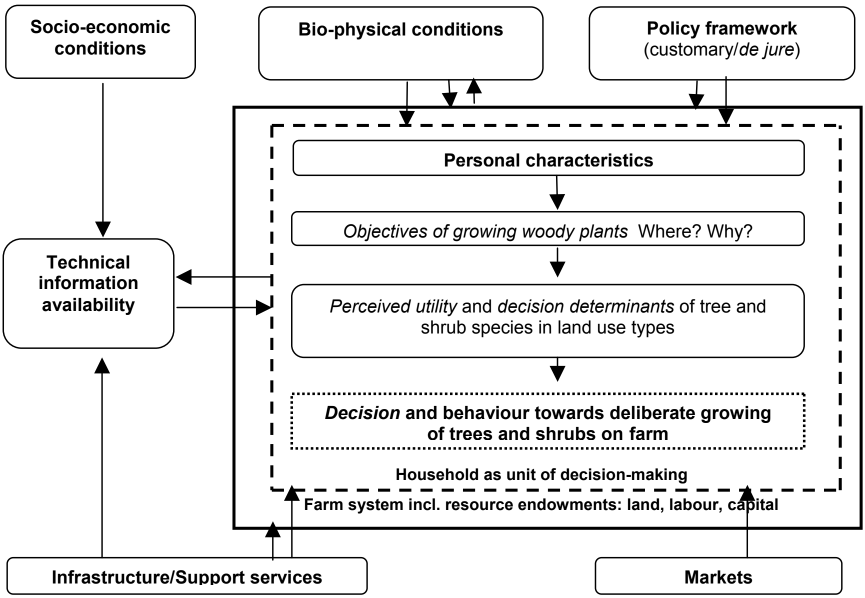
Source: modified from (Boon, 1995)

The influence diagram clearly shows the dependencies among the variables by use of arrows. It does not necessarily imply that there is a causal relation, flow of material, cash or data between the respective variables; but it rather expresses the knowledge of relevance.

3.3 Integrated model of decision making and tree integration behaviour of farm households

Decision-making in tree and shrub growing and the behaviour of smallholder farmers is influenced by external and internal factors (Beets, 1990; McGregor *et al.*, 2001) Referring to the FSA and the Behavioural Decision-Making Approach an integrated model was elaborated (Figure 3). To choose from the decision alternatives - either the deliberate growing of woody species in a particular land use type or not - base on the decision-makers' individual objective as a consequence of the capability to assess and other external influencing factors. The chance events constitute decision determinants that may hinder farmers from growing, whereas the consequences correspond to the outcome or perceived utility of growing woody plants.

Figure 3: Integrated model of external and internal decision and behaviour-influencing factors



Source: modified from (Negussie, 2003, p.26)

This study followed a two-pronged approach,

(1) to identify influencing factors in decision-making from farmers' point of view. The direct eliciting of factors from farmers' point of view is the backbone for the construction of the influence diagrams by means of perception ratings of prevailing decision determinants and the perceived utility from woody plants, and

(2) to complement internal and external factors which explain subsequent behaviour of deliberate tree and shrub growing. Herein, a multivariate modelling approach served as a tool to statistically test the factors which characterise tree and shrub growers and non-growers.

3.4 Operationalisation of factors influencing farm households' behaviour towards deliberate tree and shrub growing

In line with the integrated model operationalised factors affecting the tree and shrub growing behaviour had to be identified. The present study makes use of literature on agroforestry to incorporate determinants, which are empirically and intuitively assumed to contribute to tree grower and non-grower classification (Pattanayak *et al.*, 2002; Mahapatra and Mitchell, 2001; Rapando, 2001; Franzel, 1999; Alavalapati *et al.*, 1995; Caveness and Kurtz, 1993). Influencing factors were aggregated to factor groups corresponding to the elaborated integrated model. Subsequently, variables were assigned to groups of external factors as they are (1) socio-economic conditions, infrastructure/support services, technical information availability, policy framework, and (2) bio-physical conditions. Internal factors were represented by variables on (3) resource endowments and income/returns, as well as (4) personal characteristics.

3.5 Study design

The present study was designed as a case study. Employing the integrated model (see Figure 3) in two villages (PAs) allowed (1) contrasting between the cases regarding tree and shrub growing decisions in selected land use types and (2) cross-checking by means of variables characterising behaviour. Contrasting between the villages required the analysis and assessment at the village level, too. The research was cross-sectional, which expresses a snapshot with observation at one point in time (Neuman, 2000).

Two stages set up the methodological base in field research (1) the Rapid Rural Appraisal (RRA), and (2) the formal survey. At the first stage the gathering of qualitative data was realised by means of secondary data review, general and focus group discussion, key person interviews, transects, sketch maps, direct observation, etc. (FAO, 1995; Fink, 1995; Mwanje, 2001). The standardised questionnaire formed the backbone for household interviews at the second stage. The sampling frame consisted of a list of all registered and unregistered households settled in either the villages. In the present study, 130 households (15 per cent of total population) were systematic-randomly selected in probability proportionate to size (PPS) regarding the affiliation to intra-village settlements. The quality of data was significantly improved by triangulation of natural resource endowment, common farm practices, investment and household income, and use of woody plants.

The Likert scale turned out to be the appropriate rating technique employed for eliciting the perceptions of farmers due to the ease of use in formal household questionnaires and its clearly distinguishable, ideally equidistant scale (BORTZ and DÖRING, 1995). In particular, the farmers' perception of the utility ('very bad' to 'very good') of tree and shrub species and decision determinants ('for sure' to 'certainly not') elicited from key farmers beforehand, were subject for inclusion. The statistical modelling was accomplished by means of the Discriminant Analytical Approach (DAA). This approach is directed, firstly, to identify independent variables which significantly characterise distinguished classification attributes (of the dependent variable) and, secondly, to check and assign individuals according to discriminating variables to the affiliation to one of the classification options. The tree growing behaviour was modelled by means of the DAA.

3.6 Stages in the construction of tree growing models

The modelling followed the commonly accepted approach in analysis implementing two stages for variable selection and acceptance (MAHAPATRA and MITCHELL, 2001; CAVENESS and KURTZ, 1993),

(1) The stage of pre-selection was designed to narrow the number of variables which were assumed to be influential;
(2) Passing variables entered the stage of discriminant analysis wherein they were either dismissed or retained to be finally included in the discriminant function.

At the first stage the suitability of influencing variables is pre-tested employing

(i) the Chi-square (χ^2) test of independency, which was conducted for each single independent variable towards the binary variable of growing or non-growing;
(ii) Correlation analysis using the Spearmans Rho (ρ) and Kendall's Tau (τ) coefficients for non-evenly distributed metric-scaled and ordinal-scaled independent variables.
(iii) the Mann & Whitney's U-test for non-evenly distributed metric data. Prior to applying the U-test the distribution of attributes of variables was tested by means of
(iv) the Kolmogorov-Smirnov-test to uncover even or non-even distribution.

The level of significance to be passed for entering the next stage of analysis was set to 0.10. As a rule of thumb, variables were tested and significance accepted if there was, at least, an expected value of 2 and above to secure validity of interpretation.

At the second stage, the DAA, the main focus was to form the specific discriminant functions according to the following equation (1) (BACKHAUS *et al.*, 2003):

$$d = a + b_1 * x_1 + b_2 * x_2 + \ldots + b_n * x_n \tag{1}$$

d	Discriminant value
a	Constant of canonical discriminant function coefficients
$b_1 \ldots b_n$	Canonical discriminant function coefficients (non-standardised)
$x_1 \ldots x_n$	Values of included variables

There are two principal uses of this approach - analysis and classification. The analysis is related to the existing data. The objective is to determine the coefficients in such a way that the values of the function discriminate the growers and non-growers. The interpretation of results reveals the power of the variables in the discriminant functions between the cases under consideration. A step-wise procedure incorporating the likelihood ratio criterion was selected to consider variables for inclusion in the discriminant model. The main concern is the minimisation of the test value Wilk's Lambda (λ), Wilk's ratio of determinants, through forward selection and backward elimination. The removal of interfering variables and step-wise iteration contributed to strengthening of the model. The confidence level for variables to enter was maintained at 0.05 to ensure the entry of important variables.

Finally, the number and percentage of correctly classified observations were determined, and misclassified cases identified. The probability of a classified case to belong to the predicted group was presented in a case to case-related chart.

4 Results and Discussion

Briefing on bio-physical and socio-economic conditions in the villages A quick glance at the bio-physical and socio-economic embedding of the villages in the region describes the setting in which the individual allocation of farm resources takes place. The socio-economic conditions shall be presented by means of the access to infrastructure (Table 1).

Annual minimum temperatures reflect that frost is a major constraint in agricultural production as well as in intended tree and shrub growing in PA 2 rather than in PA 1. The EDBA and DDBA as branches of Ministry of Agiculture (MoA) shoulder the extension programs through Development Agents (DAs). Villagers in PA 2 benefit from the paved road, linking the Ginchi and Geldu town by passing through the PA. The purchase of seedlings through regional markets offers a substantial option to acquire seedlings. In PA 2 peasants use a third option to sell farm produce, namely the availability of road access to sell eucalypt poles on a contractual basis to mid-men who purchase on location.

4.1 Decision modelling component I: Objectives of growing woody plants contrasted to other livelihood activities

The deliberate growing of woody plants on-farm is pursued by farm households as integrated livelihood activity. The identification of major objectives contributed to prioritise pertinent decision alternatives in land use types and thus to better tackle the modelling of tree and shrub growing decisions for homegardens. Based on different livelihood activities the respondents were asked to give reasons for being involved in the respective activity (Figure 4).

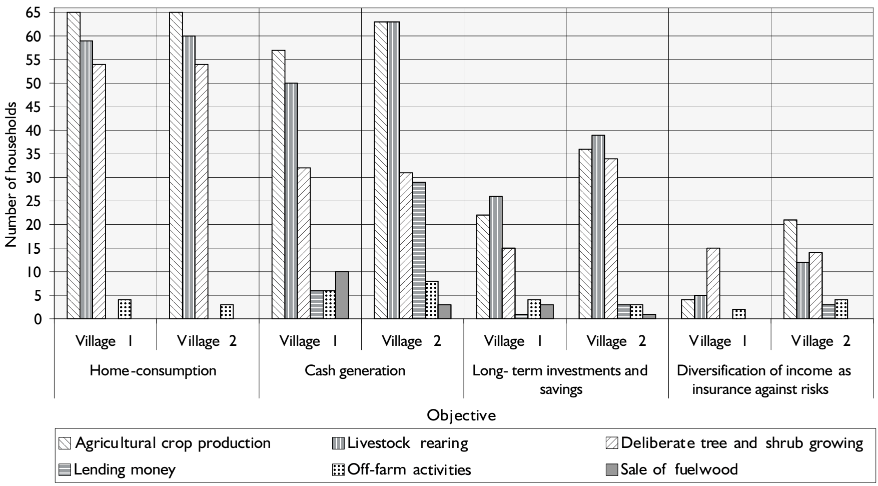
Deliberate tree and shrub growing is perceived as the third-important activity for income generation (79 per cent in PA 1, and 78 per cent in PA 2) after agriculture and livestock rearing. The predominant functions to the farmers are the availability of a stock of trees for fuel and construction purposes, the demarcation of the homestead, the provision of shelter from wind and frost as well as the availability of non-cash savings for immediate

Table 1: Selected bio-physical conditions and access to infrastructure in the two villages

Criteria	*PA 1*	*PA 2*
	Climate	
AEZ (MOA 2000)	M 2-5 "Tepid to cool moist mountains and plateau"	M 3-7 "Cold to very cold moist mountains"
Annual temperatures [°C] (MSH and MSG 2004)	Mean: 14.2 Max: 22.7 Min: 4.7	Mean: 11.9 Max: 20.7 Min: 0.8
Annual rainfall* [mm] (MSH and MSG 2004)	Mean: 992 Max: 1227 Min: 834	Mean: 1095 Max: 1418 Min: 813
	Bio-physical conditions	
Altitude [m.a.s.l.]	Mean: ∼2350 Range: ∼2200-2600	Mean: ∼2950 Range: ∼2800-3050
Topography	Flat to moderately sloping plateau, dissected by deep gullies, bordered by river valleys; rough, steep hilly territory	Temporarily flooded plains; topography similar to PA 1
Soil types by farmers	Black soil; Brown soil; Red soil+sand	Reddish-brown soil; Brown soil; Dark brown soil; Grey soil
Current vegetation	Solitary remnants/ pioneer indigenous trees/ shrubs on wood-land, agricultural ∼, degraded ∼; Eucalypts, Cupressus ssp. on-farm; Degraded natural forest patches	Solitary remnants of indigenous trees/ shrubs on grassland, agricultural ∼; Eucalypts, Cupressus ssp., etc. on-farm; Exploited Chilimo natural forest nearby
	Infrastructure	
Road access to and in village	No asphalt or paved road to urban centres; 3 km dry-weather track to main road; ∼2km step walk (30-45min) from Addis Alem town; Footpaths in village	Paved, all-weather road connection to ∼22km distant Ginchi town (no asphalt);/newline 4 dry-weather roads to Bicho, Danissa, Chobi, etc.; Footpaths in village
Water supply	Several rivers and brooks to fetch water, shared with animals, wells non-existent	
Education facilities	Primary school (1-4)	Primary and Junior sec. school (1-8)
Credits	No commercial bank access; Informal small-scale credits by neighbours	
Extension/ Research	EDBA: agricultural, livestock extension packages; EDBA: initial agroforestry extension programme in 2003	DDBA: agricultural, livestock extension packages; HARC: on-farm research in agroforestry
Markets Regional: Local:	Addis Alem: 3km step footpaths (>1h), Ihnde Gabayee: ∼8km (3h), etc., Gullet PA: ∼4km (2h), Mattala in Gaba Jimmatta PA: ∼3km (3h), Kimmoyye: 3-4km on paths (1.5h)	Ginchi town: ∼18km (∼3h walk, ∼45min by car), Geldu town: ∼15km (3.5h walk), Geba Senbeta (Geldu district): 4km (1h), Qidame gebaa, Boni market (Geldu district): 10km (2.5h walk), etc.
Off-farm employment	Wage labour; Government (PA administration, school); Craftsman business; Trade on regional markets	

*Data sets comprise an 11-year-intervall for PA 1 and a 21-year-intervall for PA 2
Source: RRA (2004)

Figure 4: Most important objectives in livelihood activities in the two villages



liquidation if needed. Woody plants are also marketed which constitutes a considerable immediate source for cash especially in PA 2 based on the road access to markets. Eucalypt trees are widely accepted for this purpose. The equal number of responses in regard to the cash generation function contrasts with the focus of PA 2 inhabitants on cash generation through farm woodlots which implies a relative stronger focus on homegarden growing in PA 1. The home consumption as crucial objective for growing woody plants in the homegarden is thus employed in decision modelling.

4.2 Decision modelling component II: Perceived utility of tree and shrub species

The utility of woody species is part of the consequences of the decision to grow trees and shrubs. It presupposes that farmers arrange their production factors in a way that enables them to achieve the identified utility. The assumption was that farmers do not grow species which are not perceived suitable. This was underlying to compile woody species which had been rated by at least ten and positively assessed by at least 50 per cent of the respondents to be good or very good for a particular utility in order to delineate trends in farmers' perception (Table 2).

Concerning the rating of species for construction purposes eucalypts appeared to be the answer to all demand although farmers' statements were influenced by the tradition of use and increasing disappearance of local knowledge regarding alternative indigenous species. Fuelwood rating values were attributed to woody species grown independently from the type of land use, which underpins the contribution of on-farm fuelwood supply to complement the exploitation of natural forests. Thus, the decision-making and subsequent behaviour of growing woody plants in homegardens is strongly directed by this particular utility. Integrated woody plants in other land use types attained worse results in either the villages which indicates that respondents did not prioritise growing woody plants merely because of fodder produce.

Table 2: Deliberately grown woody species perceived to be suitable for respective utilities

Woody species	*Village*	n_{hhGes}	n_{hhhg}	*Utility (rated being good or very good)*									
				1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Eucalyptus spp.	1	52	45	∗∗∗	∗∗∗	∗∗	∗∗			∗	∗∗	∗	∗∗
	2	58	43	∗∗∗	∗∗		∗∗				∗		∗∗
Croton spp.	1	40	21	∗					∗∗	∗	∗∗	∗∗	∗
Juniperus spp.	1	34	22	∗∗∗	∗∗∗		∗∗			∗∗	∗∗	∗∗	∗∗∗
Rhamnus spp.	1	33	33						∗	∗			∗∗∗
	2	37	37										∗
Cupressus spp.	1	16	16	∗∗∗	∗∗∗	∗∗	∗∗			∗	∗	∗	∗∗
	2	33	33	∗∗∗	∗∗		∗∗				∗		∗∗
Hagenia spp.	2	20	10	∗∗		∗∗		∗∗	∗∗	∗		∗	∗∗
Dombeya spp.	2	25	20	∗			∗	∗∗	∗		∗	∗∗	
Arundinaria spp	2	13	13				∗∗						

Utility: 1=Fuelwood, 2=Construction wood, 3=House/farm utensils, 4=Fencing, 5=Fodder, 6=Soil improvement, 7=Ornamental purpose, 8=Windbreak, 9=Shade, 10=Cash generation,
∗ rated by 50 per cent, ∗∗ rated by 75 per cent, ∗∗∗ rated by 100 per cent of respondents

The difference in perception of species between the villages has to be linked to the occurrence and non-occurrence of distinct woody species. Regarding the cash criterion, tree growing in PA 2 was more differentiated than in PA 1 explained by the perception of suitable species which concentrated on a few cash crops like eucalypts, and Cupressus lusitanica. The suitability of *Podocarpus falcatus, Olea africana, Acacia spp., Carissa edulis, Hagenia abyssinica* for cash generation was continuously mentioned in PA 1 though by a limited number of respondents (less than ten). *Rhamnus prinoides* helps to generate cash by the sale of leaves for the production of Tala, a local light brew, and was already positively tested in another study (Negussie, 2003).

4.3 Decision modelling component III: Decision determinants in growing woody species

The behaviour of respondents to grow tree and shrub species is influenced by the perceived severeness of constraining factors. Therefore, constraints were extracted from ratings which are 'likely' or 'for sure' to influence the decision to grow the referring species by respondents. The constraint arising from rodents is separately listed from other pests due to explicit emphasis by farmers. The shortage of natural resources has to be understood as the result of underlying chance events, e.g. small land holdings, poor rainfall, etc. To warrant a minimum level of prediction power woody species were exhibited in Table 3, if stated by at least ten respondents and assessed by at least 50 per cent of the respondents.

Most obviously the farmers' perception on what constraint could explicitly be attributed to what species cannot that easily be differentiated for the considerable range of woody species. An explanation is that only few species were perceived by farmers to have

Table 3: Decision determinants perceived to influence the decision to grow woody species

Woody species	*Village*	n_{hhGes}	n_{hhhg}	*Decision determinant (rated being likely or for sure)* 1	2	3	4	5	6	7
Eucalyptus spp.	1	52	45		∗			∗∗		
	2	58	43					∗∗		
Croton spp.	1	40	21		∗					
Juniperus spp.	1	34	22	∗	∗		∗∗			
Rhamnus spp.	1	33	33		∗					
	2	37	37							
Cupressus spp.	1	16	16		∗		∗	∗∗		
	2	33	33							
Hagenia spp.	2	20	10	∗						
Dombeya spp.	2	25	20							
Arundinaria spp	2	13	13		∗					

Decision determinant: 1=Shortage of seedlings, 2=Shortage of land, 3=Shortage of water, 4=Poor growth performance, 5=Competition with crops, 6=Pest and diseases, 7=Rodents,
∗ rated by 50 per cent, ∗∗ rated by 75 per cent, ∗ ∗ ∗ rated by 100 per cent of respondents

a strong negative influence on non-tree plant components. Moreover, the capability of households to shoulder the risk of income loss from non-tree plant components in homegardens was much different primarily based on the resources endowment available - a fact resulting in non-linear livelihood strategies pursued by farmers. An emerging determinant was the perceived shortage of land holding albeit being more influential in PA 1 than in PA 2. The finding coincides with the higher total number of integrated eucalypt and *Cupressus* plants in PA 2 in spite of similar holding size. The dissimilarity expresses that respondents in PA 1 realised fierce competition for land between on-farm activities and gave higher priority to other production components in intra-household land resource allocation with the exception of homegardens.

Respondents bear in mind the aggressive competition of eucalypts with agricultural crops, which could be regarded as a decisive factor to refuse growing them in the homegarden in correlation with the perceived shortage of land on the one hand. On the other hand the constraint was outweighed by the ease of protection of tree cash crops and, connected to this, the opportunity to cope with potential income loss from other land use types via liquidation. Therefore eucalypts have finally been accepted for being grown in the homegarden by the majority of respondents particularly in PA 2.

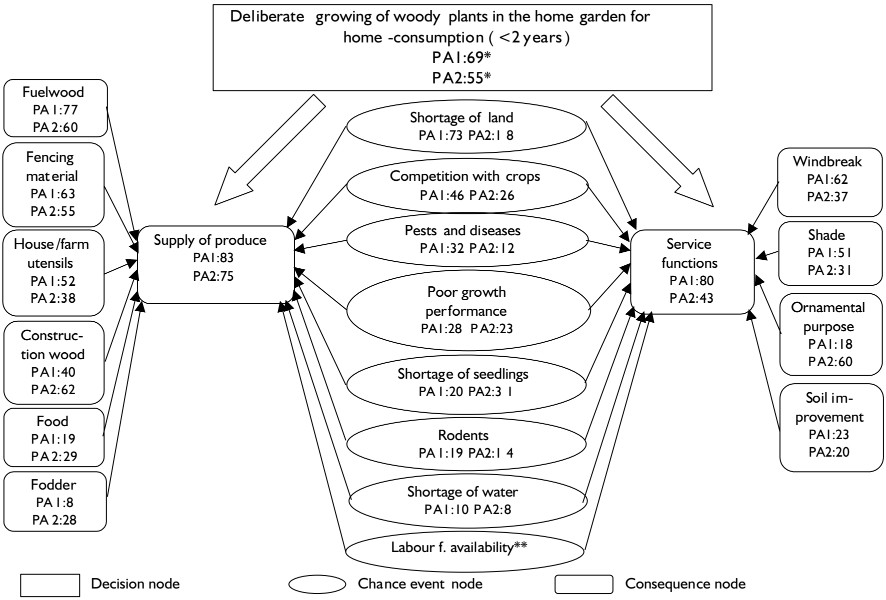
Only a minor proportion of respondents in both of the villages perceived the shortage of seedlings for eucalypts as constraining factor largely due to availability in markets. On the contrary, the short stock on seedlings for *Juniperus procera* in PA 1 was a key factor constraining the deliberate growing. Herein, it has to be taken into account that wildlings from natural forest remnants are sources of seedlings for *Juniperus* trees to a large extent.

4.4 Synthesis of decision modelling components: Growing woody plants for home consumption in the homegarden

Decision alternatives base on the respondents' involvement in tree and shrub growing. Accordingly, 45 (69 per cent) and 36 (55 per cent) of the total respondents were assigned to the grower category in PA 1 and 2 in compliance with the objective of home consumption of woody plants due to its high pertinence in farm households.

The relationships between (1) Decision alternatives, (2) Chance events incorporating decision determinants (being likely and for sure), and (3) Consequences incorporating utilities of woody species (being good and very good) are subject to the decision modelling (Figure 5).

Figure 5: Growing woody plants in homegardens for home consumption in the two villages



Statements in % of positive choice based on the number of woody species grown by the respective number of households
*Share of growers (Occurence: PA1:178, PA2:190)
**Not rated

The most important finding is that respondents' concerns for tree and shrub growing in PA 2 are much less regarding the shortage of land than in PA 1 (18 per cent and 73 per cent respectively). This result is explained by the informal subdivision of land holdings among household descendents in PA 1. Furthermore, the influence of the perceived shortage of land on tree and shrub growing coincides with the fact that the respondents' availability of fuel material in PA 2 is different than in PA 1. The majority of households in PA 2 (60 per cent) dispose over eucalypts in farm woodlots for obtaining various produce which influences the tree integration decisions in homegardens especially for fuelwood and posts for fencing.

The above utility and determinants necessitate the consideration of Multi-Purpose Tree Species (MPTS) in multi-storey arrangements like fuelwood/timber trees and small fuelwood/fencing trees at contours of homegardens particularly in PA 1. The exposure to more variable weather conditions like wind, frost, and high temperatures in PA 2 contributes to the significantly different perception of trees for shading and windbreak purposes by respondents than in PA 1.

4.5 Modelling of farmers' behaviour I: Descriptive depiction of external and internal factors influencing tree and shrub growing

There was a multitude of variables which passed in descriptive statistics at the first stage of analysis (p=0.10). Therefore, groups of relevant (1) external and (2) internal factors included in DAA are presented in brief.

(1) A range of external factors in PA 1 and PA 2 referred to the use of seedlings from various sources which indicates the respective variables to be very suitable for the intended discrimination of tree growers and non-growers. Variables pertaining to the access to fuelwood were partly significant in particular referring to the allocated household's and neighbour's land and natural forests. In contrast to PA 2 univariate statistics revealed for PA 1 that communication factors (social participation, access to extension, urban market access) are significant contributors to the discrimination in DAA. The tenure status of farm land is significant only in PA 1 which is caused by the activities regarding informal land rents. The majority of variables pertaining to inclination and soil quality in land use types possess negligible potential for the discrimination of tree growers and non-growers.

(2) The bulk of internal factors entering the second stage in analysis comes from the endowment with land and labour force, income from agricultural production, and returns from sale of produce in either the villages. Major variables linked to livestock assets were only significant in PA 2 indicating the better discrimination potential of livestock in possession. Proxies for the personal characteristics of household heads (gender, age, etc.) passed the first stage of analysis in PA 2 but stayed of minor relevance for the discrimination of the respondents in PA 1. Apparently, these factors did not possess a high explanation power as already compiled for other studies on the adoption of trees on-farm (MERCER, 2004; PATTANAYAK *et al.*, 2002).

4.6 Modelling of farmers' behaviour II: Discriminant analysis and classification

After pre-selection the above-delineated variables entered the DAA in arbitrary order and were step-wise tested according to their contribution to minimise the test value Wilk's λ. Noise variables were removed (Table 4).

In PA 1 the most important variable in discrimination of tree growers from non-growers was the use of wildlings from allocated land (standardised canonical discriminant coefficient of 0.730). It appeared that for those households, who have tree and shrub resources already available from naturally grown trees and shrubs on agricultural or pasture plots, the threshold to transplant woody plants into homegardens is lower than for households who are not endowed with these prerequisites.

Table 4: Analysis and classification results from DAA

Variables	*PA 1*	*PA 2*
Group centroid, canonical discriminant eigenvalues and Wilk's λ		
Grower	0.568	1.373
Non-grower	-1.278	-1.704
Eigenvalue	0.715	2.414
Canonical correlation	0.646	0.841
Wilk's Lambda	0.583	0.293
Level of significance	0.001	0.001
Standardised canonical discriminant coefficients		
Access to extension	0.487	
Access to credits	0.508	
Use of seedlings from farm nursery		0.446
Use of wildlings from allocated land	0.730	0.750
Use of wildlings from natural forest	0.384	
Use of seedlings from market	0.481	0.856
Cash generated from SEU*capita*a		0.464
Discrimination power (% of correctly classified households)		
Grower	70	94.4
Non-grower	91.1	86.2
Total	84.6	90.8

The access to extension by growers in PA 1 revealed that these respondents have access to communication with the development agent who may raise the farmers' awareness towards woody plants on-farm. However, the implementation of extension programs incorporating woody plant components into production in various land use types was still in its infants (in PA 1) or missing at all (in PA 2) .

The risk-averting behaviour and diversification of cash-generating activities is investigated by Senkondo (2000). Similar to homegarden growers, respondents adopting trees and shrubs also made use of natural regeneration from farm land. In PA 2, tree growers were characterised by the use of wildlings from allocated land, seedlings from farm nurseries and the purchase from markets. In addition to this, growers generated a higher amount of cash per capita from the sale of sheep within the last two years which indicates the focus on livestock production for cash generation and suggests to make use of woody plants to support this activity by complementary fodder.

The discriminating variables for tree and shrub growers and non-growers contribute to a high percentage of correctly classified households (84.6 and 90.8 per cent). This indicates the discrimination power of the variables and the prediction of other households to belong to one of the two groups according to the selected variables.

5 Conclusion

The respondents represent the total population in the villages and therefore conclusions apply for the villages. Pertinent components in the modelling of decisions are (1) the objectives of growing woody plants, (2) the utility of woody species, and (3) the decision determinants of growing woody species in the homegarden. Farmers' behaviour on tree integration in the homegarden is influenced by (4) external and internal factors related to the farm system. The following conclusions were drawn.

- The farmers' objective to grow woody plants, particularly in the homegarden, is determined by means of how woody plants primarily contribute to home consumption and, secondary, whether they warrant immediate cash generation and are appropriate for saving purposes or not.
- The road access to markets favours the farmers' perception of land use types other than the homegarden to be suitable for integrating woody plants for cash generation.
- Tree and shrub growing decisions are driven by the subjectively perceived utility of woody species for primarily fuelwood, timber-based produce, and cash generation. The use of woody species for fodder purposes is negligible and does not drive farmers to grow them in the homegarden.
- The perceived shortage of land resources and seedlings are chief decision determinants that continue to hinder farmers from growing woody plants in the homegarden. The perceived shortage of seedlings is connected to the range of sources used.
- Farmers who deliberately grow woody plants in the presence of road access to the market are characterised by a higher risk-taking capability than non-growers and thus continue to afford means of increasing the total utility from farm components by taking crop yield reduction in the homegarden into account.
- Accessible markets influence the establishment of farm nurseries and enable the purchase of seedlings by farmers which outweighs the use of wildlings from natural forests and partly overcomes missing agroforestry-related extension work depending on the household's cash capital endowment.

These conclusions can be understood as a hint to further qualify extension regarding integration of woody plants with other on-farm activities, expansion of seedlings supply particularly of multi-purpose indigenous species, and further improvement of the all-weather road network.

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