Tropentag 2006
University of Bonn, October 11-13, 2006
Conference on International Agricultural Research for Development

WOODY PLANTS IN SMALLHOLDERS' FARM SYSTEMS IN THE CENTRAL HIGHLANDS OF ETHIOPIA: A DECISION AND BEHAVIOUR MODELLING

Krause[1)], Michael and Uibrig[2)], Holm

Dresden University of Technology, Institute of International Forestry and Forest Products, P.O. Box 1117, 01735 Tharandt, Germany. Email 1) krause@uni-kassel.de, 2) druibrig@forst.tu-dresden.de

Abstract

Various strategies towards poverty reduction have been followed in rural areas of the Ethiopian highlands. In this context the contribution of woody plants to the livelihoods of farm households has widely been recognised. So, the contemporary depletion of natural forests and deforestation due to the massive use of tree produce and agricultural land expansion drives research on deliberate tree growing on-farm.

Farmers' perceptions of the utility and the constraints of locally available woody species were assumed to influence the decision making and the tree integration behaviour into current land-use types. Accordingly, the objectives of this study have been (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 growing behaviour.

The methodology of this study is based on the approaches of the 'Farming Systems' and the 'Behavioural Decision-Making'. Influence diagrams were constructed incorporating the perceived utility and decision determinants of deliberately grown woody plants. The 'Discriminant Analytical Approach' served to model farmers' tree integration behaviour referring to external and internal influencing factors. Two villages were selected in the central highlands to contrast (1) two agro-ecological zones and (2) different access to markets for tree produce. A standardised questionnaire constituted the major tool for surveying 130 systematic-randomly selected and ex-post stratified households.

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.

Key words: farming systems, behavioural decision-making, discriminant analysis, land-use pattern, non-competitive tree integration

1 INTRODUCTION

In Ethiopia, about 90% of the total population depend directly on agriculture and live in rural areas. The land use policy as pursued for about 30 years has led to the expansion of the agriculturally used land area which has preferably been at the expense of forested land. The depletion of 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 on tree-based land use practices has mainly focussed on production technologies. Less is known about the factors which influence farmers' decisions on tree growing, their perceived utility and preferred woody species.

Participatory approaches to understand local people's needs, perceptions, and objectives as well as to rely upon local knowledge and experience for decision-making are assessed undeniably 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; and (2) to embed this investigation into tree adoption studies to cross-check farmers' perceptions as decision determinants.

2 METHODOLOGY

The following two approaches constitute the elementary frame for the analysis of primary data sets on farm household's decision making and behavior.

The Farming Systems Approach (FSA)

According to BEETS a farm system "is a unit consisting of a human group (household) and the resources it manages in its environment" (BEETS 1990:163). The FSA is appropriate to embed the farmers' decision-making and behavior into the frame of influencing factors. It centers the farm household system as the basic unit of assessment (BEETS 1990:727).

The Behavioural Decision-Making Approach

The Descriptive or Behavioral Decision-Making Approach focuses on decisions incorporating alternatives that people actually take. It has been proven that the Behavioral Decision-Making Approach is highly suitable to actors in an agricultural surrounding and to address decision-making constraints (BARLETT 1980; NEGUSSIE 2003). The influence diagram, visually representing the relevance of a decision problem, reflects a snapshot of the perception in a decision situation and the relationship among decision alternatives, chance events, and consequences (BARLETT 1980; LINDLEY 2003).

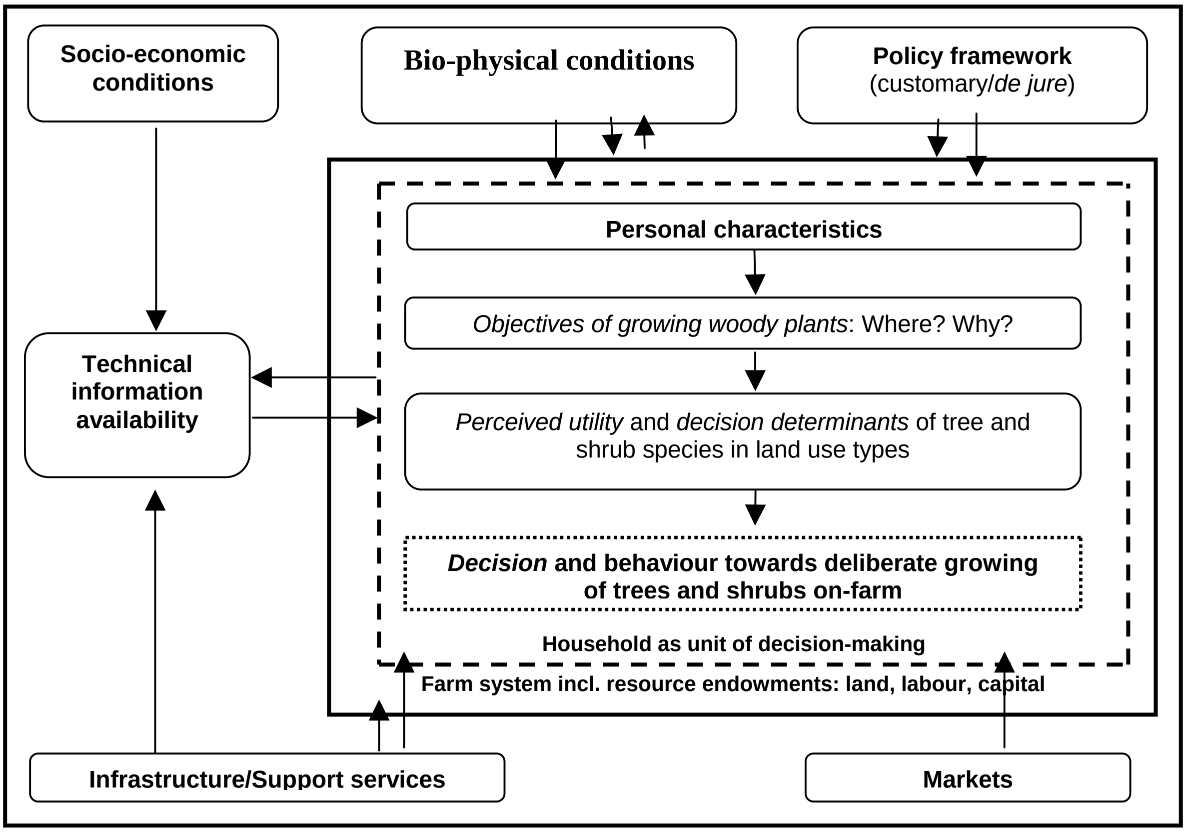
Integrated model of decision making and tree integration behaviour of farm households

Decision-making in tree 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 Behavioral Decision-Making Approach an integrated model was elaborated (**Figure 1**).

This study followed a two-pronged approach,

(1) to identify factors influencing the choice of a decision alternative based on individual objectives from the farmers' point of view by means of perception ratings of prevailing decision determinants, chance events, and the perceived utility from woody plants, consequences, and

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



Source: modified after NEGUSSIE (2003:26)

Figure 1: Integrated model of external and internal decision and behavior-influencing factors

Factors affecting the tree integration behavior had to be identified making use of empirical evidence on agroforestry adoption (PATTANAYAK *et al*. 2002; MAHAPATRA, MITCHELL 2001; FRANZEL 1999; ALAVALAPATI *et al*. 1995; CAVENESS, KURTZ 1993).

Primary data sets

Primary data sets form the backbone of the cross-sectional study covering the cropping seasons 2002/2003 and 2003/2004. Qualitative and quantitative data (NEUMAN 2000) was gathered in two villages. Criteria for the selection of locations were (1) the Agro-Ecological Zone (AEZ) based on assumed differences in tree resource endowment, and (2) the access to a paved road network as prerequisite to access regional markets (MOA 2000). Rapid Rural Appraisals (RRAs) were complemented by formal household surveys, conducted in 130 systematic-randomly selected households from March to July 2004 that relied on tools lent from empirical social sciences (BORTZ, DÖRING 1995; NEUMAN 2000; MWANJE 2001).

The Likert scale turned out to be the appropriate rating technique employed for eliciting the perceptions of farmers' on the utility ('very bad' to 'very good') of tree species and decision determinants ('for sure' to 'certainly not') (BORTZ, DÖRING 1995).

Modelling tree integration behavior

The statistical modelling of tree integration behavior was accomplished by means of the Discriminant Analysis, firstly, to identify independent variables which significantly characterize distinguished classification attributes of being tree grower or non-grower (the dependent variable). Secondly, households were checked and assigned according to discriminating variables to the affiliation to one of the classification options. The commonly accepted approach in analysis implements two stages for variable selection and acceptance (MAHAPATRA, MITCHELL 2001; KRAUSE 2005). The specific discriminant function (1) follows BACKHAUS *et al*. (2003):

$$d = a + b_1 * x_1 + b_2 * x_2 + ... + b_n * x_n \quad (1)$$

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

There are two principal uses of this approach – analysis and classification. The objective is to determine the coefficients in such a way that the values of the function discriminate growers and non-growers. The main concern is the step-wise minimisation of the test value Wilk's Lambda (λ) through forward selection and backward elimination. 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.

3 RESULTS AND DISCUSSION

Bio-physical, resource endowment and socio-economic characteristics of the villages

Selected bio-physical, resource endowment and socio-economic characteristics of the villages are given in **Table 1**.

Characteristics	Lanqisaa PA (PA 1)	Galessa Koftu PA (PA 2)
Climate and bio-physical ~		
AEZ	M 2-5	M 3-7
Min. & max. temp./a [°C]	Min. 4.7 Max. 22.7	Min: 0.8 Max: 20.7
Mean rainfall/a [mm]**	~950	~1100
Altitude [m.a.s.l.]	Mean: ~2350 Range: ~2200–2600	Mean: ~2950 Range: ~2800–3050
Soil types	Vertisol, sandy Vertisol, alluvial soil	Nitisol, silted Vertisol, alluvial soil
Current natural vegetation	Solitary tree remnants of afro-montane *Juniperus-Podocarpus* forest and *Acacia* woodlands in all land use types	Solitary tree remnants of afro-montane to subalpine mixed broadleaf-coniferous forest nearby homesteads, patches of natural forest in vicinity
Resource endowment ~		
Farm size [ha/capita]	0.22	0.23
Household size [Number of heads]	5.4	5.3
Net labour force [ME/household]	2.2	2.0
Tree seedlings, wildlings planted [Number/household/a]	~81	~83
Socio-economic ~		
Access to asphalt or paved road	No	Yes
Distance to regional market [km]	3-8	15-18
Access to mid-men (sale of poles)	No	Yes
Access to credits	No commercial bank access, informal small-scale credits by neighbours	
Agroforestry/forestry extension	Initiated in 2003: agroforestry	No
Total cash income [birr/capita/a]	215	219
Off-farm income [% of total]	42	57
Sale of wood/non-wood forest products [% of households]	32	11
Returns from sale of wood/non wood forest products [% of total]	15	25

Source: KRAUSE (2005)

Table 1: Selected bio-physical, resource endowment and socio-economic characteristics in the villages

Annual minimum temperatures reflect that frost may be a major constraint in agricultural production as well as in intended tree growing in PA 2 rather than in PA 1. Villagers in PA 2 benefit from the asphalt road, linking two towns by passing through the PA, which is expressed by the sale of wood and non-wood products on regional markets. Furthermore, the purchase of seedlings through regional markets offers a substantial option to acquire seedlings while in PA 1 wildings constitute a major source. In PA 2 farmers additionally use the option to market eucalypt poles on a contractual basis to mid-men who purchase on location through the availability of road access.

Decision modelling component I: Objectives of growing woody plants

The deliberate growing of woody plants on-farm is pursued by farm households as an integrated livelihood activity. The identification of major objectives contributed to prioritize pertinent decision alternatives in land use types and thus to better tackle the modelling procedure.

Deliberate tree growing is perceived as the third most important activity for income generation (79 % in PA 1, and 78 % 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 liquidation if needed. Woody plants are also marketed which constitutes a considerable source for cash, especially in PA 2 based on the road access to markets. The home-consumption as crucial objective for growing woody plants in the homegarden is employed in decision modelling.

Decision modelling component II: Perceived utility of woody species

The utility of woody species as part of the consequences of farmers' decisions holds true if one assumes that farmers do not grow species which are not perceived as suitable.

Concerning construction purposes eucalypts appeared to be the answer to all demand (positively rated by 100 per cent of households in the villages) although farmers' statements were influenced by the tradition of use and increasing disappearance of local knowledge regarding alternative indigenous species. The highest fuelwood rating points were attributed to eucalypts, *Juniperus spp.*, and *Cupressus spp.* 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 farmers' behaviour in growing woody plants in home-gardens is strongly directed by this particular use. 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. *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).

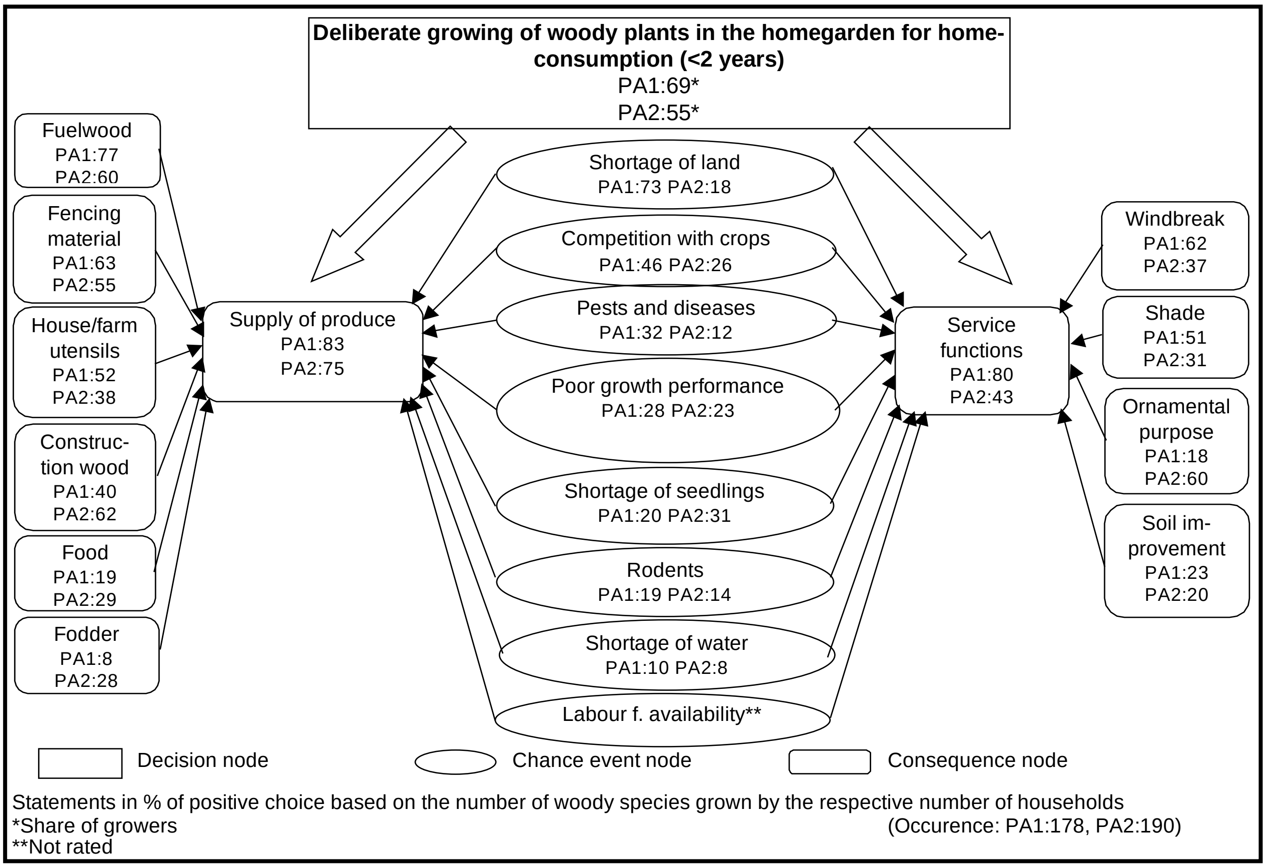
Decision modelling component III: Decision determinants in growing woody species

The decision of respondents to grow tree species is influenced by the perceived severeness of constraining factors, e.g. the shortage of natural resources as the result of underlying chance events like small land holdings, poor rainfall, etc.

Only eucalypts (in both of the villages) and *Cupressus spp.* (PA 1) were perceived by farmers to have an absolutely strong negative influence on non-tree plant components. The perception was aggravated by poor resources endowment of households to shoulder the risk of income loss from non-tree plant components in homegardens. 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 gave higher priority to other production components in intra-household land allocation with the exception of homegardens. The constraint was outweighed by the ease of protection of tree cash crops in PA 2 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 homegardens by the majority of respondents in PA 2. 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 to a large extent.

Synthesis of components: Growing woody plants in the homegarden for home-consumption

Decision alternatives are based on the involvement in tree growing. 45 (69 %) and 36 (55 %) 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. **Figure 2** further depicts chance events incorporating decision determinants (being likely and for sure), and consequences incorporating utilities of woody species (being good and very good).



Source: KRAUSE (2005)

Figure 2: Growing woody plants in the homegarden for home-consumption in two villages

Respondents' concerns for tree growing in PA 2 are much less regarding the perceived land shortage than in PA 1 (18 % and 73 % respectively). This 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 growing coincides with the fact that the respondents' availability of fuel material in PA 2 is different from that in PA 1. Several households in PA 2 (60 per cent) dispose over eucalypt farm woodlots for cash and fuelwood purposes, which mainly has an impact on tree growing decisions in homegardens.

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 contour bounds 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.

Modelling of farmers' behaviour: Discriminant Analysis and classification

After pre-selecting variables through descriptive statistics, a bulk of variables still entered the Discriminant Analysis in arbitrary order which were step by step tested by their contribution to minimise the test value Wilk's λ (KRAUSE 2005). Noise variables were removed (**Table 2**).

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
Standardized 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**

Source: KRAUSE (2005)

Table 2: Analysis and classification results from Discriminant Analysis

In PA 1 the strongest discriminating variable was the use of wildlings from allocated land. Obviously, for households which have woody plant resources already available from naturally grown trees on agricultural plots the threshold to transplant woody plants into homegardens is lower than for those which are not endowed with these prerequisites. The access to extension by growers in PA 1 revealed that these respondents have good access to the development agent which might raise the farmers' awareness towards woody plants on-farm in the presence of agroforestry-related extension.

In PA 2, tree growers were characterized by the use of wildlings from allocated land, seedlings from farm nurseries and the purchase from accessible regional 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 making use of fodder from woody plants to support this activity.

The discriminating variables for tree growers and non-growers contribute to a high percentage of correctly classified households (84.6 and 90.8 %) indicating a strong discrimination power and the prediction of other households to belong to one of the two groups.

4 CONCLUSION

The respondents represent the total population in the villages and therefore conclusions apply for the village as a whole. 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 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, if they warrant immediate cash generation and are appropriate for saving purposes.
- The road access to regional markets favors the farmers' perception of land use types other than the homegarden to be suitable for integrating woody plants for cash generation.

- Tree growing decisions are driven by the subjectively perceived utility of woody species for fuelwood primarily, timber-based produce, and cash generation. The use of woody species for fodder purposes 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.
- The access to markets for seedlings facilitates the establishment of farm nurseries. By these means the use of wildlings from natural forests is outweighed and lacking agroforestry-related extension depending on the household's cash capital endowment is partly overcome.
- In the presence of road access homegarden tree growers are characterized 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.

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.

5 REFERENCES

ALAVALAPATI, J.R.R.; LUCKERT, M.K.; GILL, D.S. (1995): Adoption of agroforestry practices: a case study from Andhra Pradesh, India. Agroforestry Systems 32. 1-14.

BACKHAUS, K.; ERICHSON, B.; PLINKE, W.; WEIBER, R. (2003): Multivariate Analysemethoden. 10th ed. Springer Publishing Company. Heidelberg, Germany.

BARLETT, P. (ED.) (1980): Agricultural decision making – anthropological contributions to rural development. Studies in Anthropology. Academic Press, Inc. New York, USA.

BEETS, W.C. (1990): Raising and sustaining productivity of smallholder farming systems in the tropics. AgBe Publishing. Alkmaar, The Netherlands.

BORTZ, J.; DÖRING, N. (1995): Forschungsmethoden und Evaluation für Sozialwissenschaftler. 2nd ed. Springer Publishing Company. Heidelberg, Germany.

CAVENESS, F.A.; KURTZ, W.B. (1993): Agroforestry adoption and risk perception by farmers in Senegal. Agroforestry Systems 21. 11-25.

FRANZEL, S. (1999): Socioeconomic factors affecting the adoption potential of improved tree fallows in Africa. Agroforestry Systems 47. 305-321.

KRAUSE, M. (2005): The occurrence and utility of trees and shrubs on-farm and the adoption potential for agroforestry development in the Central Highlands of Ethiopia. MSc. thesis. Institute of International Forestry and Forest Products, Dresden University of Technology. Germany.

LINDLEY, D.V. (2003): Making decisions. John Wiley & Sons, Ltd, The Atrium. Chichester, UK.

MAHAPATRA, A.K.; MITCHELL, C.P. (2001): Classifying tree planters and non-planters in a subsistence farming system using a discriminant analytical approach. Agroforestry Systems 52. 41-52.

MCGREGOR, M.J.; ROLA-RUBZEN, M.F.; MURRAY-PRIOR, R. (2001): Micro and macro-level approaches to modelling decision making. Agricultural Systems 69. 63-83.

MOA (2000): Agroecological zonations of Ethiopia. Addis Ababa, Ethiopia.

MWANJE, J.I. (2001): Qualitative research process. Social Science Research Methodology Series Module 2. OSSREA.

NEGUSSIE, A.D. (2003): Farm forestry decision-making strategies of the Guraghe households, Southern-Central Highlands of Ethiopia. PhD Dissertation. Institute of International Forestry and Forest Products. Dresden University of Technology. Germany.

NEUMAN, W.L. (2000): Social Research Methods, Qualitative and Quantitative Approaches. 4th edition. Allyn and Bacon. Needham Heights, Massachusetts, USA.

PATTANAYAK, S.K.; MERCER, D.E.; SILLS, E.O.; YANG, J.; CASSINGHAM, K. (2002): Taking stock of agroforestry adoption studies. Working Paper 02_04. Research Triangle Institute. Research Triangle Park, NC, USA. http://www.rti.org/enrepaper/