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# Risk in diversifying agricultural land use: Perceived impacts of woody species and livelihood diversification strategies in the Central Highlands of Ethiopia

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## Abstract

Research on sustainable land use in Ethiopia has recently been extended to locally-grown tree species outside forests. The non-competitive integration of woody species in agricultural farms may support the development of adapted land use systems by providing both goods and service functions. Thus, the control of natural resource degradation and the diversification of income, which may gain significance in livelihood diversification strategies, meet concerns of the Ministry of Agriculture about how to cope with environmental degradation and human needs within the Millennium Development Goals.

This study stresses the need for awareness towards neglected farmers' perception of potential private gains and losses from diversifying agricultural land use by integrating woody plants. The objectives are (i) to identify woody species occurring in agricultural land with special respect to farm fields, (ii) to identify the perceived suitability of woody species in terms of goods produced to diversify livelihood activities, (iii) to analyse farmers' risks perception and responses to risk in farming linked to woody species and their potential service functions.

The methodology bases on the analysis of the 'Farming System'. An integrated study approach combines a rapid appraisal and formal questionnaire survey in 130 systematic-randomly selected and ex-post stratified households in two villages. The analysis of woody species diversity in agricultural land relies on key persons' local knowledge, direct observation and botanical assessment on-station. Pair-wise and direct use rankings help to identify woody species that appeared to farmers as most promising for several uses. Likert scales reveal farmers' perceptions of risk associated with woody plants on-farm and their role in responses to risks. The analysis makes use of indicators on the farmer's access to and control over resources and is based upon descriptive statistics.

Results refer to opportunities and threats in diversified tree-integrated agricultural land use corresponding to perceived strengths and weaknesses of particular woody species that (a) are competitive/non-competitive for natural resources in farm fields, (b) constitute sources of fuelwood for diversification strategies, and (c) impact the range of potential service functions - primarily the prevention from soil erosion and soil improving capability.

**Key words**: diversification strategies, Farming Systems, local knowledge, non-competitive tree integration, perceived benefits from land use, risk perception and response

## 1 INTRODUCTION

In Ethiopia, the agricultural land had been expanded at the expense of forest for several decades. In turn, the degradation and disappearance of forest resources was accompanied by dwindling options to farm households in managing and coping with the risk of income reduction from livelihood activities. Since recently, the Ethiopian Ministry of Agriculture has recently drawn the attention to sustainable land use research acknowledging the goods and service functions of non-competitively grown woody plants outside forests.

Nevertheless, farmer's perceptions may diverge from the researcher's perceptions which influences tree and shrub adoption on-farm. Hence, studies have been initiated focussing on the farm household's acceptance of woody plants on-farm and the integration in livelihood activities.

The focus on farmer's risk perception and responses to risk in farming connected to woody species in farm fields may thus contribute to analysing pertinent decision determinants under uncertainty. Research on farmer's perceptions may further the development of adapted land use systems by taking regard of goods and service functions as appreciated farmers.

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## 2 METHODOLOGY

### *Farming Systems Analysis*

This paper follows a study that employed the Farming Systems Analysis (FSA) centring the farm household system as the basic unit of assessment from a holistic perspective (KRAUSE 2005, BEETS 1990). The FSA, as the initial methodological phase of the Farming Systems Approach, is concerned with the identification and analysis of interrelationships between the components of a farm system, such as land, labour, crops, livestock, and woody plants.

Household preferences in different farm components correspond to alternative livelihood activities and strategies which depend on the natural and socio-economic environment in which farm households take decisions in addition to the perception of risk, sources of risk and opportunities to respond to risk. The FSA is preparatory to on-farm research, which is supposed to pursue solutions for the integration of woody plants into current land use types (DAVID 1995). The analysis and assessment of woody plants adopted by farm households bases on a participatory approach.

The present study draws special attention to the woody plant component in connection with other farm components studying particularly the perceived risk that accrues to farmers from wood species in agricultural crop production and the role of woody plants in fuel material acquisition as important livelihood activity.

### *Conceptualisation of factors influencing farmer's acceptance of woody plants on-farm with special reference to uncertainties and risks*

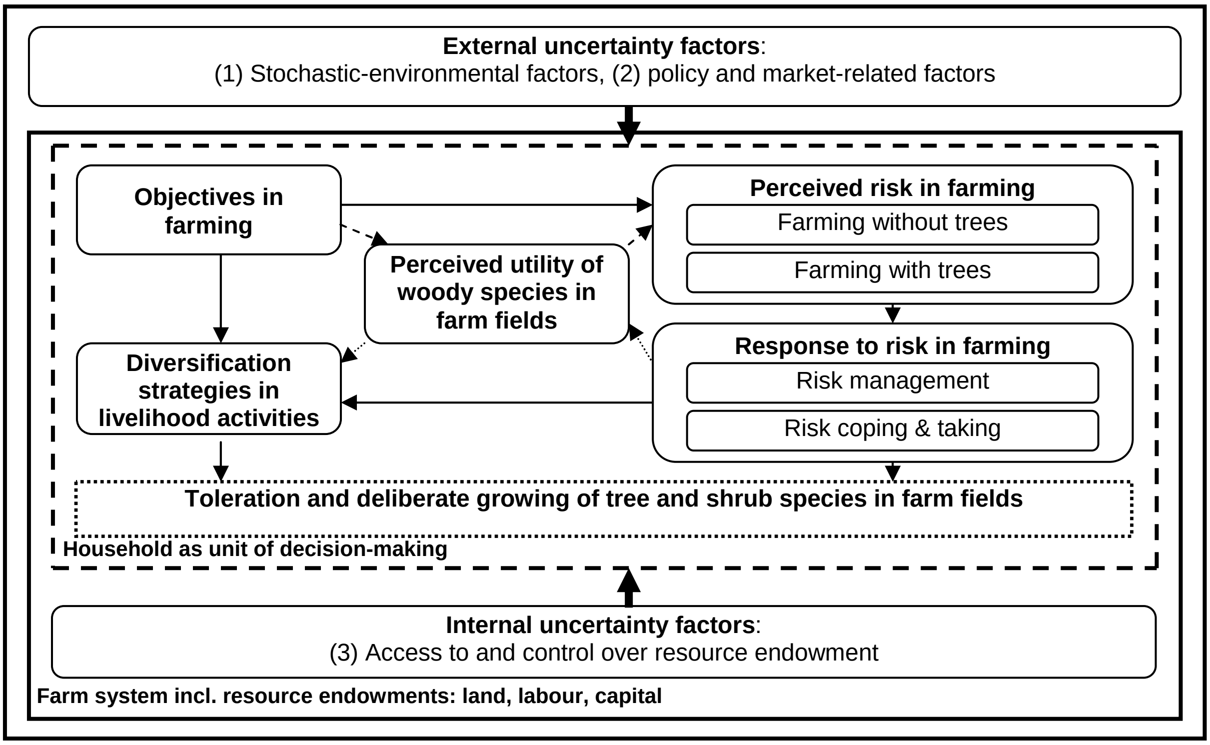
The acceptance of woody plants on-farm by farmers is influenced by external and internal factors, and is based on farmers' objectives, strategies and resources that are available to them (BEETS 1990, NEGUSSIE 2003). The characteristics of individual farmers belong to internal factors among which risk perception and risk taking are of major importance (KRAUSE 2005).

The present paper benefits from the empirical evidence of how to systematize uncertainties and risks (SENKONDO 2000). Accordingly, (1) external stochastic-environmental factors like frost and wind, (2) policy and market-related factors as well as (3) internal factors with respect to the household's resource availability like sources of seedlings, competition of farm components for nutrients, water or light have been empirically underpinned as sources of risk. Trees and shrubs in farm fields may contribute to sources of risk.

The perception of risk refers to the likelihood of various outcomes, e.g. the yield of annual crops, of a particular action, e.g. the acceptance of woody plants in farm fields. The risk of reduced annual crop yield attained focus because it tightens the pool for the household's sustenance and explains the farmer's concerns regarding trees in farm fields (DAVID 1995).

This study does explicitly focus on understanding the farmer's decisions by analysing their responses to perceived sources of risks and yield reduction in farm fields. Strategies pursued by farm decision makers comprehend (a) to reduce the exposure to a shock ex-ante by smoothing income as kind of risk management and (b) to take and cope with the risk of loss or reduction ex-post aimed at smoothing the consumption (CROLE-REES 2002). Particular tree and shrub species may be worthwhile to be considered for risk reduction which results from the farmer's need for various wood and non-wood products.

From above depictions on (I) external and internal uncertainty factors as sources of risk, (II) the perception of risk and (III) ex-ante and ex-post responses to risk highlighting diversification strategies a conceptual frame has been elaborated (**Figure 1**).




Source: modified from Negussie (2003:26) and Krause (2005:12)

Figure 1: **Conceptual frame of external and internal uncertainty factors influencing the farmer's risk perception and response to risk**

The risk perception of the farmer on trees and shrubs in farm fields lead to strategies in managing and coping with these risks, which take into account both alternatives as well as uncertainties (CROLE-REES 2002). It is assumed that the farmer prioritises secured crop income over tree and shrub benefits. Therefore, actions may be taken to stabilize crop production and avoid or remove competing woody species. However, the perceived mutual benefits such as supporting services in production and provisioning services in addition to non-competitiveness of woody species with annual crops may help to respond to risks in different livelihood activities.

Evidently every farm household pursues diversification strategies even though woody plants are always embedded in responses as one of a multitude of alternatives (SENKONDO 2000).

These strategies base on criteria of the individual access to and control over resources which have previously been elaborated by means of a Discriminant Analysis (KRAUSE 2005).

### *Study design and primary data sets*

The research paper draws on a case study which was designed cross-sectional expressing a snapshot with observation at one point in time covering primary data sets on the cropping seasons 2002/2003 and 2003/2004 (KRAUSE 2005). The acquisition of primary data sets was backboned by 130 interviews conducted in a survey of systematic-randomly selected households from March to July 2004. Pre-phased appraisal surveys delivered complementary qualitative and quantitative data gathered from secondary and primary data sources by lending tools from empirical social sciences such as Likert scales, direct rankings, pair-wise rankings, triangulation, (NEUMAN 2000) and on-station botanical assessments.

Primary data sets were acquired at household level in two villages to contrast (1) the occurrence and distribution of woody species on-farm with focus on farm fields by number of households, (2) the sources of risk identified, the perceived risk in farming and responses to risk with special reference to woody species, and (3) the integration of woody plants in livelihood diversification strategies based on the utility of woody species. Data on the response to risk in farming relies on the Structured Questionnaire Approach which is helpful in obtaining data on risk perception and response (SENKONDO 2000). Additionally, villages were contrasted which required the analysis and assessment at the village level, too.

Descriptive statistics based on mean values, standard deviation, percentiles, minimum/maximum values, the univariate Chi² test of independency and correlation analysis using Spearmans Rho coefficient helped to analyse data sets.

## 3 RESULTS AND DISCUSSION

### *Identified woody species and the utility in patterns of spatial arrangement in farm fields*

In the villages a total of 39 and 33 tree and shrub species belonging to 27 and 20 families were identified in PA1 and PA2 respectively. Trees make up to 49% in PA1 which constitutes 1.4 times as much as in PA2 indicating the richness of total tree species in PA1. Arguably, the altitude is less favourable for trees at above 3000 m.a.s.l. and forest remnants have been intensively used for various purposes in PA2 (KRAUSE 2005).

Woody species occur in land use types out-farm and on-farm. Patches of dry afro-montane natural forests in PA1 encompass *Podocarpus spp.*, *Juniperus procera*, *Olea africana* and *Hagenia abyssinica*. Afro-montane to subalpine mixed broadleaf-coniferous natural forest nearby PA2 is dominated by *Juniperus procera*, *Podocarpus spp.* and *Ficus spp.*. On-farm, the composition of indigenous species in homegardens is complemented by exotic species like *Eucalyptus spp.* and *Cupressus spp.* (in total 21 and 23 species in PA1 and PA2) whereas in farm fields and pasture land, remnants from open woodlands (16-18 species) like *Acacia spp.* dominate in PA1 and a number of species from previously dense natural forests are to be found in PA2 (7-15 species). Woody species as they are identified in land use types are listed by KRAUSE (2005).

Utility shapes spatial patterns in the distribution of woody species by their occurrence in land use types (KRAUSE 2005). Hereafter, farm fields are subject to further explanations due to being the backbone in agriculture for subsistence (KRAUSE 2005, KRAUSE ET AL. 2007).

Fuelwood, posts for fence, farm utensils and fodder are major goods – provisional functions for livelihood diversification – obtained from woody species in addition to services like the prevention from soil erosion or improvement of soil fertility – supporting functions in farming (ibid.). Fuelwood constitutes the outstanding utility of trees and shrubs in both of the PAs (83% and 100% of 18 and 15 species occurring in PA1 and PA2).

Services are linked to the spatial arrangement on plots as they refer to the beneficial interaction of the woody plant component with the agricultural farm component. Non-competitiveness in farm fields is determined by the purposively selected scattered, contour or linear, clustered, and block arrangement of woody species in space.

Dispersed soil-improving and shade-providing trees explain about 75% of the arrangement patterns in farm fields in PA1, and about 50% in PA2. At the contour bounds of land plots woody species demarcate individual land, stabilize the soil and prevent crops from being browsed and trampled by animals. Live and dry fences serve the latter purpose and farmers identified the usefulness of thorny small trees and shrubs such as *Carissa edulis*. Linear arrangements are designed to prevent edges of gullies from further erosion. *Eucalyptus globolus* and *Eucalyptus camaldulensis* are arranged in blocks in PA2 nearby roads to access markets, being efficiently managed and to avoid possible interferences of crop production (KRAUSE 2005). Promising properties of wood and non-wood tree parts, encouragement of farmers to grow eucalypts, and, raising awareness during the last three decades are obvious reasons (ibid.).

### *Woody species perceived suitable for the diversification of fuel material*

Fuelwood is a major good included by farmers in the acquisition of fuel material for heating and cooking as livelihood activity for sustenance (KRAUSE 2005). Farmers perceive woody species being differently suitable in providing fuelwood for the diversification of fuel material to attain objectives regarding self-sustenance which drives the decision to avoid or at least tolerate them with one species favoured over another independent of the patterns of spatial arrangement (ibid.).

Pair-wise rankings of woody species for fuelwood commenced with the identification of criteria which were nearly identical in the villages and thus have been subsumed to be the (1) steady and durable burning, (2) workability, (3) ease of inflammability, (4) strength of heat, and (5) ease of keeping the flame burning. The three most crucial species from pair-wise rankings were recorded to be *Carissa edulis*, *Eucalyptus spp.*, *Juniperus procera* in PA1 and *Chamaecytisus palmensis*, *Hagenia abyssinica* and *Olea africana* in PA2 although multiple species led to the same result in evaluation. *Acacia spp.* is among the few species that meet the expectations of respondents because dry wood from old remnants of acacia woodlands was assured to make excellent fuelwood. In addition, species that haven't been listed by farmers on top priority but are commonly used for fuelwood will be included in further analysis (KRAUSE 2005: Appendix 8).

### *The production risk in farming and the perceived role of woody species in farm fields*

#### *Comparative perception of annual crop yield reduction by the presence of trees and shrubs*

The production risk in farming refers to the expected outcome of resource allocation decisions or actions taken for different farm components under uncertain conditions. A relationship has been established between the risk of reduced yield from annual crops and influencing factors such as the occurrence of trees and shrubs in farm fields. It was assumed that respondents are familiar with the potential crop yield that is attainable based on their experience in farming and information exchange. High attention was given to the comparability of perceived yield reduction, having given rise to nominating a period of one year as time frame (**Table 1**).

The higher share of perceived annual crop yield reduction with woody plants (48% and 23% in PA1 and PA2 respectively) contrasted to farm fields without woody plants (26% and 8% respectively) coincides with the reluctant behaviour to deliberately grow woody species in farm fields in PA1. About 33% and 56% of all tree adopters in PA1 and PA2 use farm fields for this purpose, with the share in PA2 determined by having farm woodlots established. Such farmers appreciate the utility obtained from farm woodlots and may continue to afford means of increasing the total utility from farm components by taking annual crop yield reduction into account (KRAUSE 2005).

| **Presence of woody plants in farm fields** | **HH involved** | | **Perceived likelihood of annual crop yield reduction** [% of $n_{PA1}$, $n_{pa2}$] | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | **PA1**$^{(1)}$ | | | | | | **PA2**$^{(2)}$ | | | | |
| | $\mathbf{n_{PA1}}$ | $\mathbf{n_{PA2}}$ | 1 | 2 | 3 | 4 | 5 | | 1 | 2 | 3 | 4 | 5 |
| Farm fields without woody plants | 64* | 65 | 3 | 23 | 52 | 19 | 3 | | - | 8 | 57 | 34 | 2 |
| Woody plants in and around farm fields | 64* | 65 | 0 | 48 | 25 | 23 | 3 | | - | 23 | 43 | 34 | 0 |

*1 missing case,
**Perceived likelihood of annual yield reduction: 1**= For sure, **2**= Likely, **3**= As likely as unlikely, **4**= Unlikely, **5**= Certainly not,
$^{(1)(2)}$= **Monte-Carlo significance (2-tailed) of $\chi^2$ at $^{(1)}$ $\alpha$=0.01; $^{(2)}$ $\alpha$=0.041** (presence of woody plants in farm fields and the perceived likelihood of annual crop yield reduction)

Source: KRAUSE (2005)
Table 1: **Perceived risk of annual crop yield reduction in farm fields with and without integrated woody plants**

*Perceived sources of risk in farming attributed to the role of woody species in farm fields*

The farm decision maker perceives sources of production risk in farming attributed to the presence of particular woody species. The perceived utility of the woody species in question is off-set by sources of risk in farming which justifies removal. The mutually agreed upon sources of risk from woody species are specified by respondents to be (1) the competition for nutrients, water, or light and slow litter decomposition as well as (2) disturbances of the workability like shallow-rooting which disturbs field preparation or difficulties in crop harvest (KRAUSE 2005).

In two villages, eucalypts clearly rank first not being tolerated or grown in and around farm fields with 46% and 74% of the total number of respondents in PA1 and PA2. Farmers' awareness concerning competition effects varies but eucalypts were ranked to be the most aggressive possible competitors with agricultural crops for nutrients and water. Broad use range puts them at a separate state regarding being accepted along farm fields as observed in adjacent PAs (ibid.). A practice to extenuate the competition for water in PA2 is to establish eucalypt woodlots nearby springs and plots close to brooks (ibid.). The adverse effect of contour-planted eucalypts on crop productivity has been underpinned by on-farm research trials nearby the villages (KIDANU ET AL. 2004) and contrasted to indigenous species by FETENE, BECK (2004).

*Cupressus lusitanica* is appreciated for the contribution to total income-smoothing through fuelwood notwithstanding the partial negative impact on annual crops (KRAUSE 2005). The respondents' perception coincides with their actual behaviour to rather prefer *Cupressus lusitanica* in home compounds (ibid.). Additionally, exceeding branches of *Juniperus pocera* in PA1 or branched out thorny *Rosa abyssinica* in PA2 disturb the agricultural crops harvest. DAVID (1995) highlights the lateness in lopping creating difficulties in harvest.

Several sources of production risk in farming do not arise from woody species like (a) stochastic-environmental factors such as frost, diseases and rodents, (b) market-related factors e.g. the fluctuation of prices for fertilizer and herbicides, (c) household's resources availability and management-related factors such as the nutrient status of land or the availability of draught power and seeds. They put woody species into perspective for risk reduction even though the (d) shortage of available agricultural land determines the extent to which the farmer is willing to allocate land to trees and shrubs as overarching farm constraint (ibid.).

*Perceived risk-reducing influence of woody species in farming*

The respondents manage the risk of yield reduction in farming from other sources than woody plants and income reduction from livelihood activities on-farm by several utility-bearing woody species to be tolerated or grown in farm fields (KRAUSE 2005). Services perceived by farmers comprise the (1) prevention from soil erosion, (2) soil fertilization, and (3) wind-breaking function. The (4) protection against frost gains importance to respondents in PA2 due to their vulnerability to sudden frost in higher altitude than PA1 and is supplemented in the villages by the (5) perceived missing negative impact on crops (ibid.).

Though woody species like *Croton macrostachyus* in PA1 or *Hagenia abyssinica* in PA2 are ranked first by the outstanding majority of responding households (58% and 76% respectively) for producing easily decomposing litter and thus raising the nutrient status of soils they are not necessarily grown (ibid.). At least farmers have developed a positive attitude to particular woody species in farm fields (ibid.). Leguminous woody species like *Acacia spp.* are positively perceived based on locally known properties to enrich the soil and to cause apparently better growth of crops nearby such trees.

The total number of species stated by farmers in PA1 and PA2 (19 and 13 respectively) is considerable higher than for species avoided (13 and 9 respectively). Details on varying utility are provided by farmers but concern a comparably heterogeneous conglomerate of various woody species which are preferred by only few respondents each showing a greater divergence in farmers' perceptions than for species avoided. This is traced back, *inter alia*, to the varying experience in farming (KRAUSE 2005).

*Diversification as response to the risk of income reduction from selected livelihood activities*

The farmer responds to the risk of income reduction from fuel material through the diversification of produce and sources incorporating fuelwood obtained from trees and shrubs on-farm among crop residues and cow dung from allocated, neighbour's and communal land.

About 90% and 91% of tree-owning households (58 in PA1 and 52 in PA2) grow fuelwood trees on-farm. But 12% and 31% of the households with fuelwood trees on allocated land in PA1 and PA2 deliberately grow them in farm fields indicating the subordinated role of farm fields in deliberate growing of fuelwood trees.

Gathering from tolerated trees and natural regeneration on allocated land is conducted, in contrast to woody plants grown, by 93% and 42% of the households possessing trees in farm fields in PA1 and PA2 and takes into account twigs and branches after the pruning of trees (ibid.).

Natural forests and communal land serve as additional sources for fuelwood acquisition principally when coping with the shortage of fuel material. Thus, the continuing disappearance of these out-farm sources for fuelwood contributes to raising awareness of the farmer for alternatives, e.g., woody plants grown on-farm or purchased.

The characterization of households by the access to and control over resources helps to understand diversification strategies (KRAUSE 2005). In brief, adopters of trees in farm fields of PA1 discriminate from non-adopters by the availability and use of wildlings on-farm, agricultural land areas which are insufficiently available underpinned by the small size of land plots in possession and the fact that areas do not bear sufficient annual crop yields independent of the presence of woody plants (ibid.). Households obtaining fuelwood from farm fields in PA2 are endowed with more land in possession, better control over land indicated by shorter distances and time needed to access land plots. They also hire labour force in times of peak workloads (ibid.). Moreover, they have more productive assets available and better access to seedlings from varying sources than households without woodlots in farm fields (ibid.). Thus, adopters of fuelwood trees in farm field can rely on a higher risk-taking capability than non-adopters to better deal with the risks of reduced fuel material income.

## 4 CONCLUSIONS

Woody species have been identified by their occurrence out-farm and on-farm with respect to farm fields. The utility obtained from woody species for diversifying the acquisition of fuel material as livelihood activity as well as the services appreciated to respond to sources of risk in farming have been contrasted to the perceived risk in farming originating from woody species. Conclusions apply for households in the villages being the parent population of samples drawn.

- The occurrence of woody species in farm fields is driven by the utility depending on (1) goods for diversifying livelihood activities primarily fuelwood, and (2) complementary service functions primarily soil stabilization, fertilization and protection from frost perceived by farmers.
- Farmers perceive woody species to be both sources of and means to respond to production risk in agriculture.
- The perceived competition of woody species with annual crops for natural resources coincides with the reluctant behaviour to grow particular woody species in farm fields.
- Stochastic-environmental sources of agricultural production risk are mitigated by non-competitively occurring woody species through service functions perceived by farmers.
- Although woody plants in farm fields contribute to manage and cope with the risk of income reduction from acquiring fuel material as major livelihood activity their importance continues to stay secondary to other sources of fuel material.

These conclusions can be understood as a hint to initiate on-farm research on non-competitively grown woody species in farm fields and to identify trade-offs between the farmer's perceptions and economic and ecological assessments by researchers under consideration of farm resource endowments.

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