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Exploration of farmers' tree species selection for coffee agroforestry in Bukomansimbi district of Uganda

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ABSTRACT

Tree species selection in coffee agroforestry systems is ultimately determined by the plantation owner. Therefore, understanding the decision making process behind tree species selection is essential if current coffee agroforestry practices are to be improved. Based on a survey among coffee famers in Bukomansimbi district, several criteria for tree species selection for coffee agroforestry were identified including optimal shading, nutrient addition to the soil and product diversity. While all three criteria influenced tree species selection, product diversity was found to be the most valued criterion with tree species that provide multiple products such as *Ficus natalensis*, *Artocarpus heterophyllus*, *Maesopsis eminii*, *Mangifera indica* and *Persea americana* commonly used in coffee farms. Generally, tree species selection by coffee farmers is based on the productivity of the selected species, along with its ecological functions and social acceptability.

Key words: Coffee agroforestry, farmers, tree species, selection criteria

Highlights

- Optimal shading, nutrient addition and product diversity primarily influence farmers' tree selection;
- In practice, product diversity is the major determinant of farmers' tree selection;
- Farmers' knowledge of tree species selection can supplement scientific methodologies and approaches.

Introduction

Coffee agroforestry provides a number of products e.g. fruits, timber, fodder, and herbal medicines and a range of important environmental services such as soil fertility preservation, microclimate amelioration, biodiversity conservation, and carbon sequestration (Sinclair and Laxman 2000; Soto-Pinto et al. 2007). The need to ameliorate adverse climatic conditions as well as meet the demands of 'green consumers' have further highlighted the importance of agroforestry systems (Beer et al. 1998; Albertin and Nair 2004). However, the potential of coffee agroforestry can only be realized when appropriate agroforestry tree species are selected (Huxley 1999; Souza et al. 2010). As such, tree species selection for coffee agroforestry is a subject of growing interest to a number of stakeholders including farmers, researchers and development workers. The Diagnostic and Design (D&D) methodology (Raintree 1989) has been tried as a scientifically-based rationale to clarify the role and function of a given tree species, as well as focus further research on priority tree species most likely to succeed in a given ecological zone. In reality, most famers in Africa are rarely guided by scientific rationales. Despite this, most tree species on their farms meet their immediate local needs.

In Uganda, for instance, coffee farmers have been growing trees on their farms for generations (Kang and Akinnifesi 2000) with hardly any strict adherence to scientific rationales. Currently, local knowledge particularly with regards to tree species selection in coffee plantations has not been fully explored. This knowledge has the potential to be useful in developing research activities on coffee agroforestry, improving coffee husbandry and associated tree management as well as supplementing scientific rationales. Therefore, an understanding of the farmers' criteria for tree species selection could form a basis for promotion of ecologically sound, economically acceptable and socially complaint tree species for coffee agroforestry systems (Nair 1993).

Materials and methods

Study area

Bukomansimbi district ($00^0 10^/$ S; $31^0 39^/$ E) (Figure 1) is located in the banana-coffee zone in the Lake Victoria crescent of Uganda. Its altitude is 1200 m above sea level and the soils are clay and sandy loams. The climate is semi-humid with a rainfall range of 1200 – 2000 mm, usually peaking in May and November, while the temperature ranges from 10-30^{o}C. The population density of Bukomansimbi is 248 persons per km^2 (Uganda Bureau of Statistics 2007). Crop farming is the main economic activity with coffee and banana being the main cash and food crops respectively. Bukomansimbi was selected for this study because of its location in the Lake Victoria crescent. Robusta coffee *(Coffea canephora)* is indigenous to Bukomansimbi, which is a major producing district of the crop.

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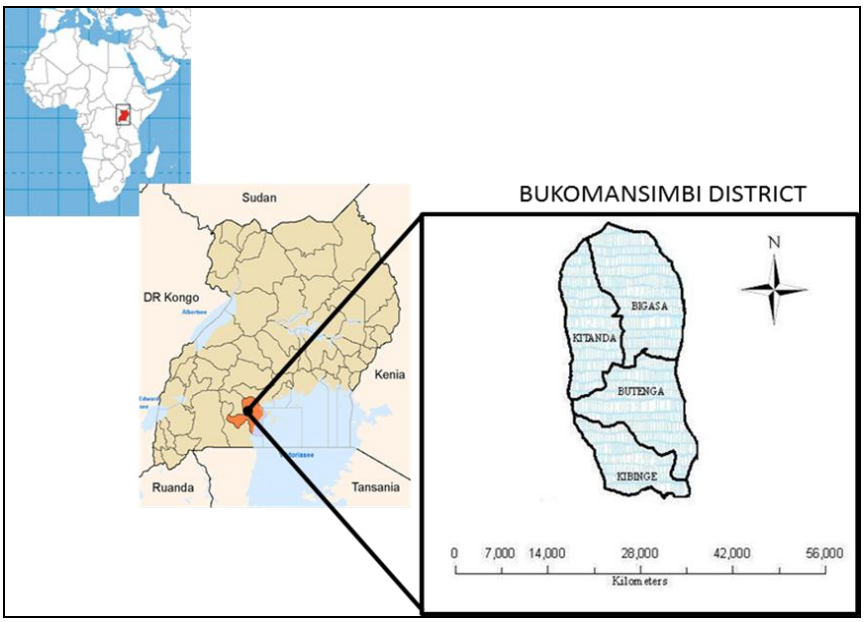


Figure 1. Location of the study area (Source: SCC-VI Agroforestry Project database)

Data collection and analysis

Data were collected through a survey (Bryman 2008) in which a semi-structured questionnaire (de Vaus 1996) was developed, pretested and administered to a total of 72 coffee farming households selected through a snowball sampling method (Bailey 1978). The snowball sampling method was used because the population of coffee farmers in Bukomansimbi was not well enumerated, making it difficult to locate samples by other sampling methods (Castillo 2009). On farm observations and informal discussions were incorporated into the household survey to increase the validity of data collected. Key Informants Interviews (de Zeeuw and Wilbers 2004) were used to acquire a deeper understanding into coffee agroforestry in relation to Bukomansimbi. In addition, a workshop was specifically organized (Franzel et al. 1996; Franzel et al. 2001; Souza et al. 2010) to explore the coffee farmers' criteria for tree species selection. The workshop participants were drawn from a list of coffee farmers obtained from the government agricultural extension officers.

Data collected were cleaned, coded and entered into SPSS (Statistical Package for the Social Sciences; Version 18.0) software) for analysis. Frequencies and percentages were computed and in order to determine the statistical independence between the most grown tree species and their uses, cross tabulation analyses using Chi-square tests ($p< 0.05$) were conducted.

Results

Social and farm characteristics of the coffee farmers in Bukomansimbi district

A total of 72 coffee farmers (51 males and 21 females) were sampled during the household survey (Table 1). The average age of the sample was 49.6 (±1.3) ranging from 25-80 years. Around 70% of the sampled farmers had attended primary school while about 22% and 7% attended secondary school and tertiary institutions respectively. Only 1% of the sampled farmers did not attain any level of formal education. Of the sampled farmers, 90% had land size between 1 and 5 ha (Table 1). The majority of farmers (76%) had spent more than 10 years in Robusta coffee farming. Furthermore, most of the farmers rely on Robusta coffee (*Coffea canephora*) as the main source of household income. Other crops grown included: bananas (*Musa paradisiaca*), vanilla (*Vanilla planifolia*), maize (*Zea mays*) beans (*Phaseolus vulgaris*), tomatoes (*Lycopersicon esculentum*), cabbages (*Brassica oleracea*) and nightshade (*Solanum aethiopicum*).

Farmers' criteria for selecting tree species in coffee agroforestry

The criteria used by coffee farmers for tree species selection in coffee agroforestry in Bukomansimbi were grouped into primary and secondary (Figure 2). The three primary criteria were: optimal shading, nutrient addition to the soil and product diversity. According to the farmers, optimal shading was the most important criterion with the following indicators: semi-deciduousness, small leaves, high branching and long tree rotation (Figure 2). The secondary criteria included tree attributes such as strong anchorage, less labor intensiveness, attraction of pollinators and non-hazardousness. There was no prioritization among the secondary criteria.

Suitability ranking of tree species by coffee famers

Farmers ranked the common tree species grown with coffee in Bukomansimbi based on the above criteria (Figure 2). The three top-ranked were *Albizia chinensis, Ficus natalensis* and *Albizia coriaria* (Table 2).

Table 1. Characteristics of coffee farmers in Bukomansimbi

Variable	Frequency (n)	Percentage (%)
Sex		
Male	51	70.8
Female	21	29.2
Formal education		
None	1	1.4
Primary	50	69.5
Secondary	16	22.2
Tertiary	5	6.9
Farm size (ha)		
>1.0-≤2.0	14	19.5
>2.0-≤3.0	21	29.2
> 3.0-≤4.0	14	19.4
>4.0 -≤5.0	15	20.8
>5.0	8	11.1
Years in Robusta coffee growing		
1 - 10	17	23.6
11 - 20	33	45.8
21 - 30	12	16.7
>31	10	13.9

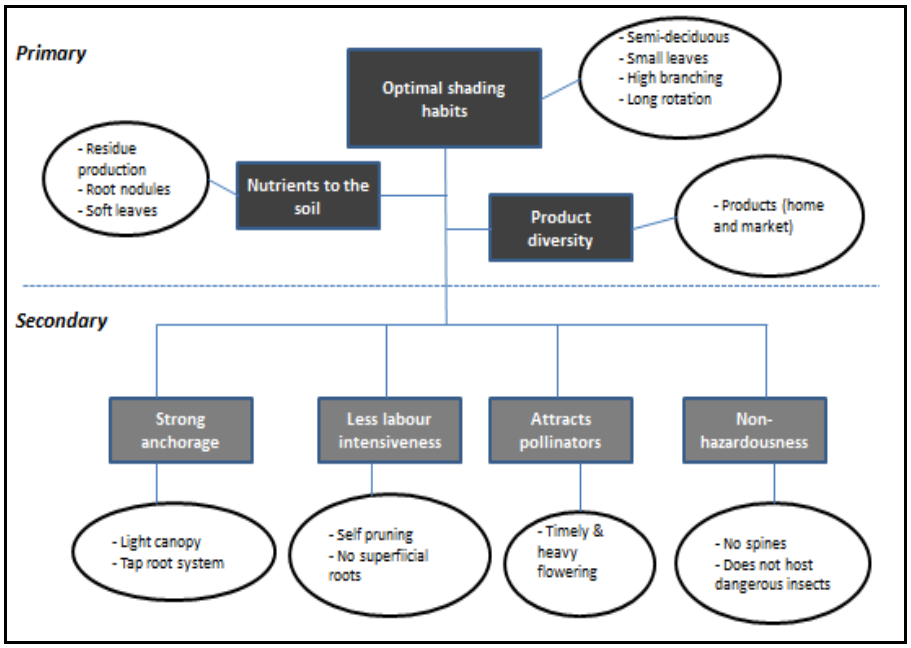


Figure 2. Criteria (boxes) and indicators (ovals) used to select trees used in coffee agroforestry systems in Bukomansimbi district (Source: Field survey 2012)

Tree species diversity on coffee farms

Despite some tree species being highly ranked by farmers for coffee agroforestry (Table 2), they were less integrated into coffee farms (Table 3). The most commonly grown tree species in coffee plantations were *Ficus natalensis*, *Artocarpus heterophyllus*, *Maesopsis eminii*, *Mangifera indica*, *Persea americana* and *Albizia chinensis*. A Chi-square test of independence between the most grown tree species and products showed a very high dependence ($p<0.000$) for each of the above-listed tree species.

Discussion

Farmers' criteria for selecting tree species in coffee agroforestry

It is important that the tree species selected for coffee agroforestry meet farmers' expectations. The selected species need to fulfill a variety of needs, ranging from socio-economic to environmental (Scherr 1995). Some of the criteria and indicators for tree species selection in coffee agroforestry presented in this study (Figure 2) were similar to those identified by Soto-Pinto et al. (2007) and Souza et al. (2010) such as labor intensiveness and product diversity. Farmers in Bukomansimbi also identified additional criteria (Figure 2) such as optimal shading, nutrient addition to the soil and product diversification.

Table 2. Suitability ranking of tree species for coffee agroforestry

Trees species	**Criteria**							**Score**	**Rank**
	Optimal shading x4	Nutrients to soil x3	Product diversity x2	Strong anchorage x1	Less labour intensiveness x1	Attracts pollinators x1	Non-hazardous x1		
Albizia chinensis Merr.	88	69	40	23	21	16	22	271	1
Ficus natalensis Hochst.	96	60	60	-	23	-	20	259	2
Albizia coriaria Welw.	88	45	32	25	4	8	20	222	3
Maesopsis eminii Engl.	112	-	44	22	16	-	4	198	4
Calliandra calothyrsus Meisn.	-	75	36	15		20	2	148	5
Polyscias fulva Hutch. et Dalziel	92	-	10	22	13	-	2	139	6
Sesbania sesban Merr.	-	54	36	7	3	18	12	130	7
Persea americana Mill.	16	24	60	10	12	-	2	124	8
Artocarpus heterophyllus Lam.	24	-	60	17	7	-	8	116	9
Markhamia lutea K.Schum	21	-	34	20	13	-	8	96	10
Mangifera indica Blume	-	-	60	10	5	-	3	78	11
Grevillea robusta A.Cunn. ex R.Br.	20	-	30	19	2	-	6	77	12
Faidherbia albida (Delile) A.Chev.	12	27	-	9	5	17	-	70	13
Carica papaya L.	-	-	48	2	8	-	-	58	14

Numbers in the columns are obtained by multiplying the number of farmers who voted for the tree species by the respective weight (x4, x3, x2, x1) of the criterion according to the scale of importance developed by the farmers.

Table 3. Trees, their uses and main products according to their overall frequency

Tree species	**Frequency (n)**	**Uses**				**Main products**						
		S	F	P	A	1	2	3	4	5	6	7
Ficus natalensis Hochst.	61	48	43	47	-	59	-	12	34	2	35	6
Artocarpus heterophyllus Lam.	37	7	-	37	-	5	37	-	-	-	5	-
Maesopsis eminii Engl.	29	16	-	28	-	11		28	-	-	-	-
Mangifera indica Blume	22	2	-	21	-	-	22	-	-	21	-	-
Persea americana Mill.	22	4	-	21	-	-	22	-	-	22	-	-
Albizia chinensis Merr.	13	11	12	5	-	6	-	7	-	3	-	-
Sesbania sesban Merr.	9	-	9	7	4	9	-	-	-	-	9	-
Grevillea robusta A.Cunn. ex R.Br.	9	2	-	9	-	6	-	6	-	9	-	-
Albizia coriaria Welw.	9	7	5	3	-	4	-	5	-	1	-	-
Polyscias fulva Hutch. et Dalziel	8	8	-	7	-	8	-	-	-	-	-	-
Markhamia lutea K.Schum	7	-	-	6	-	2	-	-	-	1	-	6
Carica papaya L.	2	-		2	-	-	2	-	-	2	-	-
Calliandra calothyrsus Meisn.	2	-	2	-	2	1	-	-	-		-	-
Moringa spp. Adans.	2	-	-	1	-	-	-	-	-	2	-	-

S = Shade, F = Fertility, P = Products, A= Attracts pollinators. 1 = Firewood, 2 = Fruits, 3 = Timber, 4 = Bark cloth, 5 = Medicine, 6 = Fodder, 7 = Poles. The numbers in the columns of uses and main products indicate the frequency of farmers acknowledging a particular use or main product.

Optimal shading was the most important primary criterion for selecting tree species for coffee agroforestry in Bukomansimbi. This was identified as the most valuable primary criterion because achieving the optimal level of shading is a crucial component of coffee agroforestry. Although tree shade is necessary in coffee plantations, it is essential that it is not too dense. This is particularly important during flowering if high yields are to be attained (Soto-Pinto et al. 2000). Optimal shading is indicated by semi-deciduousness, small leaves, high branching and long rotation of trees. Semi-deciduousness is a valuable attribute as light is necessary for high yields. It also renders pruning unnecessary, thereby saving labor and time (Souza et al. 2010). Small leaves are another beneficial attribute as they allow light to pass through the tree canopy to coffee and minimize rain drop coalescence and subsequent drip damage (Beer 1987). Optimal shading is also determined by high branching with well spread crowns and long rotation of trees for similar reasons (Beer 1987).

The ability of a tree to add nutrients to the soil was another highly regarded criterion in tree species selection for coffee agroforestry. The presence of root nodules was indicative of a tree species' ability to add nitrogen to the soil. Although there are arguments that the fixed nitrogen is generally low on its own to justify the inclusion of legumes in agroforestry systems (Fassbender 1987), others have observed that the impact of the fixed nitrogen depends on the site conditions (Szott et al. 1991; Neupane and Thapa 2001) and that shade trees in coffee should be nitrogen fixing since this may reduce the cost of fertilizers (Beer 1987; Souza et al. 2010). In addition, readily decomposing litter was identified as a key source of nutrients, enhancing soil fertility (Beer 1987; Kuntashula and Mafongoya 2005; Souza et al. 2010). Farmers observed that green tree leaves decompose much faster than yellow leaves. Notably, tree species such as *Artocarpus heterophyllus* and *Mangifera indica*, which shed yellow leaves, did not readily add nutrients to the soil. Research has shown that yellow leaves have a high C/N ratio which reduces their rate of decomposition (Li et al. 2011).

Product diversification is also a key determinant when farmers are selecting a particular tree species. For instance, while they are not the most suitable species, it was found that farmers were growing fruit trees in their coffee farms (Table 2). This was further confirmed by a Chi-square test (p<0.000) where tree species selection in coffee agroforestry was found to be highly dependent on tree products. These products are crucial to farm households, especially during periods of uncertainties (Beer 1987; Arnold 1995; Roothaert and Franzel 2001). Valuable tree products from coffee agroforestry in Bukomansimbi included firewood, fruits, fodder, timber, bark-cloth, and herbal medicine. These products can be an important source of income for farmers (Soto-Pinto et al. 2007; Snelder and Lasco 2008; Kiyingi and Gwali 2012). Therefore, trees in coffee agroforestry systems contribute to food and income security.

The farmers reported that they did not give as much priority to the secondary criteria when selecting tree species. However, there are certain tree attributes in the

secondary criteria which are very important for coffee agroforestry. For instance, strong anchorage with a rigid taproot system minimizes wind throws (Beer 1987). Additionally, self-pruning trees and no superficial roots minimize crown and root pruning labor costs respectively. The use of scented flowering trees to attract insect pollinators like honey bees (*Apis mellifera)* to coffee plantations is also key, as insect pollinators are crucial for high coffee yields (Vergara and Badano 2009). It is particularly important that the flowering times of the trees planted to attract pollinators coincides with that of coffee. Lastly, harm to both coffee plants and humans needs to be minimized by selecting anti-pathogen host and thornless tree species respectively.

Tree species diversity on coffee farms

The diversity of tree species in Bukomansimbi (Table 3) was low compared to other studies conducted in areas of traditional coffee cultivation (Rice 1999; Albertin and Nair 2004). It is possible that the low diversity found was due to a lack of planting material coupled with a high population density. Land fragmentation as a result of population pressure is evident in Bukomansimbi, as the majority of farmers only own between 2-3 ha of land. Some tree species, although highly suitable for coffee agroforestry, were not commonly used in the studied coffee farms (Tables 2 and 3). This is due to the fact that tree species selection is usually associated with meeting household food security and income generation (Souza et al. 2010).

The most commonly grown tree species by coffee farmers in Bukomansimbi were valued more for their products than any other beneficial attributes**.** This finding affirms the popular belief that the tree species used in agroforestry systems are most highly valued for their multipurpose nature (Nair 1993; Oluka-Akileng et al. 2000; Neupane and Thapa 2001). In developing countries, firewood is the most important source of energy (cf. Kuntashula and Mafongoya 2005; Rice 2008), thus the use of traditional shaded coffee cultivation systems for firewood is imperative (Peeters et al. 2003; Kiyingi and Gwali 2012). According to coffee farmers in Bukomansimbi, *F. natalensis* is their most preferred tree species for firewood and fodder as it sprouts easily (Beer 1987; Tabuti et al. 2003; Agea et al. 2010). This characteristic means that once planted, a continuous supply of these products is assured. In addition, the bark from *F. natalensis* is used for bark cloth which has significant cultural values to the local communities in Uganda (Groth and Kamwesiga 2002; Howard and Nabanoga 2007). Furthermore, fruits from fruit trees contribute significantly to home consumption and household income (Rice 2011; Kiyingi and Gwali 2012).

Generally, for a tree species to be integrated in coffee agroforestry, it has to meet productivity expectations of the farmer and be ecologically and socially suitable. . However, it is worth noting that finding an ideal tree species for coffee agroforestry, especially over a vast area, is difficult (Nair 1993). For Bukomansimbi, an ideal tree species has to produce marketable domestic products and fulfill both ecological and social functions (Figure 3). Determining the ideal species for use in coffee agroforestry systems is important for the promotion of coffee agroforestry research and implementation in Bukomansimbi district and beyond.

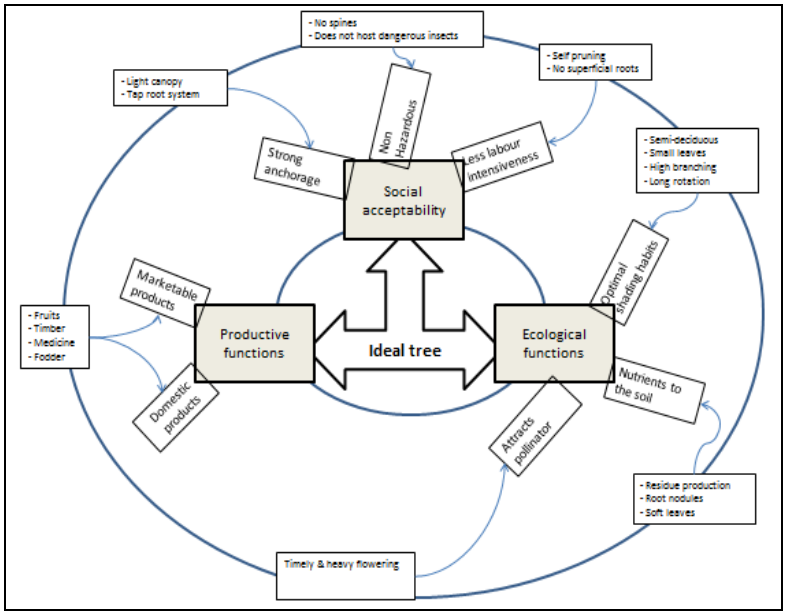


Figure 3. An ideotype tree specification for coffee agroforestry in Bukomansimbi

Conclusion

Coffee farmers in Bukomansimbi base their selection of tree species for coffee agroforestry on a number of primary criteria including optimal shading habits, nutrient addition to the soil and product diversity. While given less priority by the farmers, the secondary criteria are also important for coffee agroforestry. The secondary criteria include strong anchorage, less labor intensiveness, attraction of

pollinators, and non-hazardousness. In order to ensure adoptability of tree species, scientists working in agroforestry research must take note of these criteria. These criteria can supplement earlier methodologies and approaches such as the D&D (Raintree1989) and the multipurpose tree selection approach (von Carlowitz 1989).

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Photograph 1. A typical coffee agroforestry landscape in the study area