ORIGINAL ARTICLE

Shade Tree Selection and Management Practices by Farmers in Traditional Coffee Production Systems in Jimma Zone, Southwest Ethiopia

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Abstract

There is a traditional practice of forest management in coffee producing communities in Ethiopian moist Afromontane forests to increase coffee production. The practice involves removal of big canopy trees with excessive shade and selectively retaining specific tree species as preferred shade trees. This study was initiated to assess farmers' traditional coffee shade tree selection and management practices. Data on shade tree selection and management were collected through semi-structured interviews of 120 informants and two focus group discussions in two localities with distinct coffee forest characteristics. The result revealed that, farmers' decision in the removal and retention of canopy trees is based on their knowledge of the tree species attributes such as height, crown architecture, leaf size and deciduousness, leaf decomposition rate, impact on soil fertility, effect on coffee bean quantity and quality. Based on these criteria, *Albizia schimperiana* Oliv., *A. gummifera* (J.F.Gmel.) C. A. Sm, *Acacia abyssinica* (Hochst.) ex. Benth. and *Millettia ferruginea* (Hochst.) Baker, all nitrogen fixing leguminose species with spreading crowns, intermediate and manageable height, small deciduous compound leaves and fast rate of litter decomposition were considered as preferred coffee shade trees by farmers. Coffee shrubs growing under the shade of these trees are considered by farmers as having higher productivity and superior cup quality. In areas of high population pressure, the shade tree selection is intense that only the preferred shade trees are available in the coffee forests, while in areas where population density is sparse. This indicates that there is a compromise between coffee production and other ecosystem services such as honey production, where some trees such as *Schefflera abyssinica* (A. Rich) Harms. are retained for their flowers for foraging bees and *Olea welwitschii* (Knobl.) Gilg & G.Schellenb. for their height and shape for putting traditional beehives. Therefore, the impact of the reported quality of shade trees by farmers in improving coffee productivity and cup quality must be scientifically proved to recommend the practice to other areas.

Key words: *Coffea arabica*, shade tree, traditional coffee management, coffee quality

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INTRODUCTION

Ethiopia is the center of origin and diversity of Arabica coffee (*Coffea arabica* L., Rubiaceae) (Gole et al. 2002; Anthony et al. 2002) and coffee use and domestication in Ethiopia dates back for centuries (Schmitt 2006; Meyer 1965). *C. arabica* is an understorey shrub, indigenous to the Afromontane moist forests in Southwest Ethiopia (Anthony et al. 2002). Excessive shading or light interception by the upper two to three canopy strata of various tree species is known to decrease growth and grain productivity of the crop (Kufa and Burkhardt 2011). Soto-Pinto et al. (2000) reported a decrease in coffee production for shade cover above 50% from Chipas, Mexico. As a result, there is a long local tradition of managing coffee forests for coffee production by thinning the canopy through removal of some tree species (Schmitt et al. 2009; Gole et al. 2008). These coffee forest managers are typically small holder farmers who derive most of their income from coffee as it is the only cash-crop for many of them (Gole et al. 2008).

The traditional coffee management practice includes thinning of the forest canopy by purposively retaining certain tree species in the semi-forest (SFC) and semi-plantation coffee systems (SPC) (Schmitt et al. 2009; Aerts et al. 2011; Hundera et al. 2013). Tree selection is a complex phenomenon, especially for diverse, multi-strata and low-input plantations where farmers' knowledge and the forces of secondary succession interact (Soto-Pinto et al. 2007). Escamilla et al. (1994) reported that the traditional tree species selection for coffee shade in Mexico was according to utilitarian criteria and degree of environmental adaptation and crop compatibility. Another study in Mexico confirmed that the coffee shade tree species selection is based on farmers' knowledge of the morphological, physiological and ecological features of native tree species (Soto-Pinto et al. 2007). An assessment conducted in Costa Rica on preferences of coffee shade trees showed that farmers' decision on tree retention in their plantation was based on tree attributes such as height, crown width, leaf size and deciduousness and litter decomposition rate (Albertin and Nair 2004). Farmers also retain some trees in their coffee farms for additional purposes (fruit trees, firewood or honey production) (Soto-Pinto et al. 2007; Muleta et al. 2011).

In their assessment of socio-economic benefits of coffee shade trees in Ethiopia, Muleta et al. (2011) mentioned that farmers retain shade trees in their coffee farms based on leaf and crown characteristics, tree height and their impact on coffee yield. They also reported farmers' knowledge on the disadvantages of growing coffee without shade. The majority of their respondents reported that growing coffee in full sun resulted in stunted growth which ultimately resulted in coffee yield reduction and quick wilting of the coffee shrubs, bean size reduction, increases in weed problems, unfavorable effects of heavy rain and hail damage which pose withering/dropping of flowers, frost damage, soil erosion and exhaustion of soil fertility due to lack of fertilizing "shade tree leaves".

In the traditional coffee management systems in Southwest Ethiopia, farmers select certain species of trees as coffee shade tree and remove others which they believe having an adverse impact on the coffee shrub growth and productivity. Even though coffee production and management has been practiced for centuries in this part of Ethiopia, there are very few systematic studies on coffee shade tree selection criteria and management practices in

Southwest Ethiopia forest coffee growing areas (but see Muleta et al. 2011). Thorough understanding of the traditional coffee management techniques is however, essential for promoting sustainable agroforestry systems based on the existing local knowledge or for eventually recommending sustainable alternatives. Therefore, the objectives of this study were (1) to identify farmers' preferences on coffee shade tree selection in traditional multi-strata coffee forests in southwest Ethiopia and (2) to compare these preferences with the current shade tree composition in these coffee farms

TMATERIALS AND METHODS

Description of the study area

Two study sites were selected for an in-depth study of traditional coffee farming communities, rather than adopting a broader and shallower approach involving larger and more dispersed sampling areas (Walker and Sinclair 1998).

The selected study sites were known as Garuke in the Manna district and Afalo and Kacho (hereafter Gera locality) in the Gera district in the Jimma zone of the Oromia National Regional State, South West Ethiopia (Fig 1). The Garuke study site comprises 31 coffee forest fragments (size 1ha-100ha) managed for coffee production, while the Gera study site is in the Gera forest, a large continuous forest belonging to the Belete Gera National Forest priority area with a size over 100,000ha (Cheng et al. 1998).

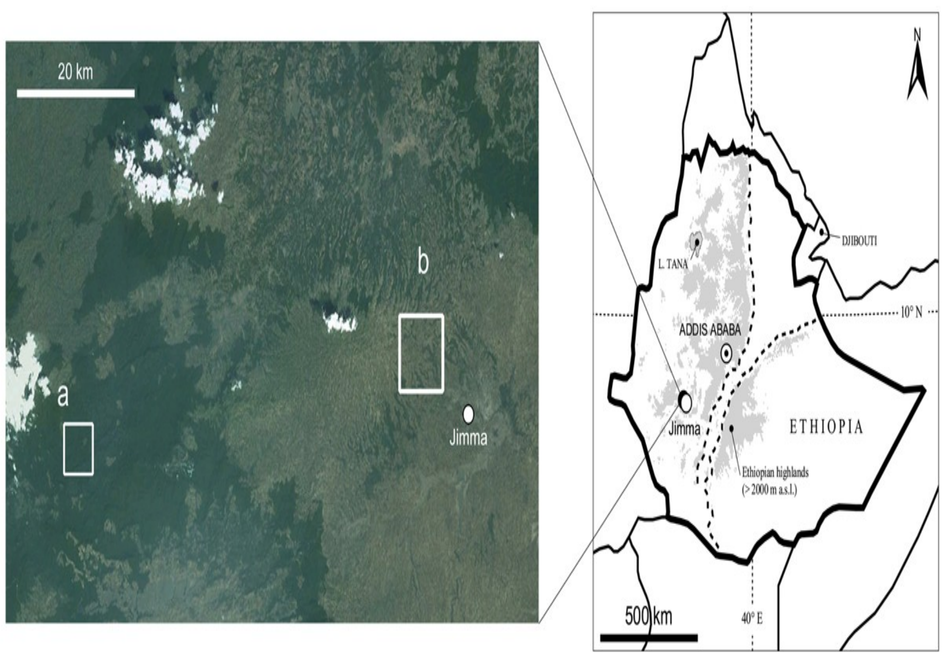

Figure 1. Afromontane moist forests in Southwest Ethiopia. (a) the forest coffee and (b) the semi-forest coffee/semi-plantation landscape. Satellite imagery© 2012 DigitalGlobe, GeoEye and Cnes/Spot Image, via Google Earth**.**

The local communities in the area share similarities in language (Afaan Oromo), religion (Muslims) and customs. In the Garuke area the management practice is a combination of SPC and SFC (Hundera et al. 2013a; Aerts et al. 2011) whereas in the Gera area the management system is SFC near pathways and homesteads and a forest coffee system (FCS) deep in the forest (Hundera et al. 2013). Therefore, in Gera the study has focused on the management in the SFC only, as this is the most widespread system. The interviewed farmers' holdings in the coffee farms range from 0.5ha hectare to 5ha.

Method of data collection

One hundred twenty (120) informants were purposely selected from the two localities (66 from the Garuke locality and 54 from the Gera locality), with the assistance of local administrators and development extension workers, based on age (more than 30 years), possession of coffee farms in the forest, depth of knowledge, willingness to participate and articulateness (Walker and Sinclair 1998). The researchers who conducted the field data collection had more than three years of field work experience in the localities and developed good working relationship with the farmers, spoke the local language and had a good knowledge of the site conditions. Information on the farmer's knowledge and practice on coffee shade tree selection and management was collected by administering semi-structured interviews, consisting of closed and open ended questions. The coffee management practice questions included shade tree selection criteria and management practices, knowledge about the selected shade tree attributes, and their effect on soil fertility, coffee yield and quality, practice of intercropping and application of inorganic fertilizers. In addition, two separate focus group discussions comprising eight individuals each were conducted at the two localities to be used in clarifying the information gathered through the questionnaire.

In parallel with the interviews, the composition of the shade tree composition in coffee farms belonging to interviewed farmers was recorded in 24 plots in Garuke and 12 plots in Gera. A total of 36 plots of size 20m x 20m were inventoried and all trees and shrubs with height more than 5m were recorded and their DBH was measured.

Data analysis

Age of the respondents was categorized into two groups (30-45 yrs and > 45 yrs). The association between age, sex and place of residence (Garuke or Gera) of the respondents and (i) management practice, (ii) coffee shade tree selection criteria and (iii) preferred shade trees management practice was evaluated using χ^2-tests. The close ended questions were analyzed using frequencies and percentages. Management practice was categorized as a) removal of big canopy trees, retaining selected and preferred trees and regular annual or biannual slashing; and b) intermediate management practices such as removal of some trees and shrubs, intermittent slashing and no specific shade tree selection. Preferred shade tree selection criteria were a) crown shape, tree height, leaf size and decomposition rate and b) No specific selection criteria (availability) and additional benefit (e.g. preferred for their flowers in apiculture). The preferred shade tree species were categorized as a) *Albizia, Millettia* and *Acacia* and b) no specific tree species selected but the combination of the former and other species such as *Cordia africana* Lam. and *Croton macrostachyus* Hochst. ex Delile . Responses to the open-ended questions were categorized into themes and then analyzed using frequencies. The identified themes were (1) the reasons given why specific shade tree characteristics are preferred, and (2) the advantages mentioned for the specific tree species. Responses from the focus group discussion were used for clarifying responses to the interview questions. The shade tree species abundance and basal area was computed for the two localities.

RESULTS

Coffee shade selection criteria and management practice

The age and sex distribution of the respondents of the two localities is summarized in Table 1.

Table 1. Sex and age composition of the respondents

		Garuke	**Gera**
Sex	male	50	44
	female	16	10
Age (years)	30-45	26	24
	>45	40	30

There was no significant association between age and sex of the respondents and coffee shade management practices or criteria to select shade tree species, or the preferred shade species. But place of residence (Garuke vs. Gera) was significantly associated with shade tree selection and management (Table 2).

Table 2. The effect of age, sex and place of residence (locality) of respondents on shade tree selection and management practice in traditional coffee production systems in Jimma Zone, Southwest Ethiopia

	χ2	**df**	**Asymp. Sig. (2-sided)**
Age *vs* management	5.206	1	0.277
preference	0.28	1	0.597
criteria	0.691	1	0.406
Sex *vs* management	1.64	1	0.281
preference	0.875	1	0.350
criteria	0.727	1	0.394
Locality *vs* management	91.848	1	0.001
preference	13.33	1	0.001

	$\chi 2$	df	Asymp. Sig. (2-sided)
criteria	1.16	1	0.001

Eighty eight percent (88%) of the respondents in Garuke manage their coffee farms by removal of big canopy trees, retaining selected and preferred trees and regular annual or biannual slashing of the undergrowth whereas only about 28% in Gera area practice similar management activities. In Garuke all interviewees (100%) reported that the preferred shade trees selection depends on their crown shape, height, leaf size and litter decomposition rate but in Gera only 18% of the respondents reported use of the same criteria (Table 3).

Table 3. Comparison of coffee shade management, preferred trees and selection criteria in traditional coffee management system in Jimma Zone, Southwest Ethiopia

		Garuke No (%)	**Gera No (%)**
Shade management	removal of big canopy trees, retaining selected and preferred trees and regular annual or biannual slashing	58 (88)	15 (28)
	intermediate management practices such as removal of some trees and shrubs, intermittent slashing and no specific shade tree selection	8 (12)	39 (72)
Preferred tree	crown shape, tree height, leaf size and decomposition rate	66 (100)	10 (18)
	No specific selection criteria (availability) and additional benefit (e.g. preferred for their flowers in apiculture).	0 (0)	44 (82)
Shade selection criteria	*Acacia, Albizia* and *Millettia*	64 (97)	0
	no specific tree species selected but the combination of the former and other species such as *Cordia africana* and *Croton macrostachyus*.	2 (3)	54 (100)

From the focus group discussion and the interviews, it was found that the management practice in the two localities was different. In Garuke, the management activity included removal of big trees, slashing of competing herbs and shrubs including the seedlings of canopy trees once or twice a year. In Gera, the management activity was the removal of few big trees and some competing shrubs and small trees and the slashing is not regularly done on an annual basis, as the proliferation of herbs and small shrubs is not as high as in the Garuke area, due to the dense tree canopy cover and canopy closure (91 and 89 % in Gera and 60 and 58% in Gera respectively).

For almost all respondents in Garuke, the major criteria in selecting shade tree species were based on attributes of the trees they consider will affect coffee growth and productivity, such as medium and manageable tree height, wide crown architecture, small and deciduousness leaves, fast growth rate, moderate foliage density and fast litter decomposition rate (Table 4).

Table4. Coffee shade tree preference criteria by farmers in Garuke traditional coffee management system

Tree characteristics	Preference	Frequency of respondents (%)
Tree height	Short (< 10m)	4 (5)
	Intermediate (10-15m)	60 (92)
	Tall (> 15 m)	2 (3)
Tree crown	Spreading (wide)	65 (98)
	Narrow	1 (2)
Leaf size	small	64 (97)
	Large	0
	No effect	2 (3)
Leaf lifespan	Deciduous	65 (98)
	Evergreen	0
	No effect	1 (2)
Leaf decomposition rate	Fast	66 (100)
	Slow	0
	No effect	0

Almost all interviewed farmers in Garuke (92%) responded that trees that have intermediate height (10-15m) are preferred for coffee shade (Table 4). The major reasons cited for this preference were 1) provision of good shading to coffee shrubs better than too large trees with higher crowns and 2) ease of management for pruning. The majority of farmers (98%) preferred trees with spreading crowns as favorable shade trees, rather than those with a narrow crown as it provides better shade for coffee plants than a narrow crown.

Leaf size was considered an important characteristic by the majority of the farmers interviewed (97%) (Table 5). Their justifications were: light can easily filter through them as compared to larger leaves; small leaves do not harm coffee flowers and fruits when they are shedding as they do not accumulate on flowers and branches; and also the rate of decomposition is high, improving soil fertility.

Table 5. Preferred shade tree species by farmers and their attributes in coffee farms in traditional coffee management system in Jimma Zone, Southwest Ethiopia

Species	leaves	decomposition rate	deciduous	crown	Coffee yield	Coffee quality
Albizia gummifera	small	fast	yes	wide	high	high
A. schimperiana	small	fast	yes	wide	high	high
Acacia abyssinica	small	fast	yes	wide	high	high
Millettia ferruginea	small	fast	yes	medium	high	high
Croton macrostachyus	large	fast	yes	medium	medium	medium
Syzygium guineense (Willd.) DC.	small	slow	no	medium	low	low

Based on these attributes the most preferred shade tree species were *Albizia gummifera*, *A. schimperiana, Millettia ferruginea* and *Acacia abyssinica* all belonging to the family Fabaceae (Table 5). Trees producing litter with faster decomposition rate are selectively retained in the coffee farms. But species such as *Croton macrostachyus* and *Cordia africana* although not preferred shade trees, are common in the coffee farms as shade trees and are retained next to *Albizia* and *Acacia* trees in the Garuke area. Despite their big leaves, farmers believe that they have a fast decomposition rate, and contribute to increased soil fertility. *Croton macrostachyus* is especially dominant at forest margins as they are the fastest growing trees in the area and giving shade at places where farmers convert farmlands to coffee plantations. There are canopy tree species which are not preferred by the farmers as shade tree because of associated impacts on the productivity and survival of the coffee shrubs. They believe that non-deciduous trees with deep shade such as *Syzygium guineense* compete for water with coffee during the dry period. Also they believe the leaves of *S. guineense* do not decompose fast and do not improve soil fertility. Other important criteria for removing certain species were based on their potential to attract pests and disease. They believed for example, *Sapium ellipticum* (Hochst.) Pax will attract worms and insects that affect coffee berries when retained in the coffee farms

The management practice and the selection of shade trees in Gera differ greatly from that in Garuke. All the interviewed farmers mentioned the same shade tree species as suitable for improving coffee productivity and quality similar to that in Garuke, but in practice the shade tree strata is more diverse and the mentioned preferred shade trees have abundance of about 2% (Table 6). About 90% believe that coffee shrubs grown under the shade of the preferred trees bear more berries and that the quality is superior to that of other shade trees.

Table 6. Common shade tree species, their abundance and basal area at both Garuke and Gera coffee forests in Jimma Zone, Southwest Ethiopia

Species	**Family**	**Abundance/ha**		**Basal area (m^2/ha)**	
		Garuke	**Gera**	**Garuke**	**Gera**
Albizia gummifera C.A.Sm.	Fabaceae	50	8	3.09	1.05
A. schimperiana Oliv.	Fabaceae	47	2	3.20	0.006
Croton macrostachyus Hochst. ex A.Rich.	Euphorbiaceae	50	8	3.51	1.34
Millettia ferruginea Hochst	Fabaceae	24	38	1.27	0.32
Syzygium guineense DC.	Myrtaceae	20	122	5.89	3.71
Acacia abyssinica (Hochst.) ex. Benth.	Fabaceae	6		0.06	
Allophylus abyssinica **(Hochst.) Radlk.**	Sapindaceae	4	4	0.273	0.02
Cordia africana Lam.	Boraginaceae	4	8	0.03	0.35
Prunus africana (Hook. f.) Kalkman	Rosaceae	4	20	1.83	0.3
Erythrina abyssinica Lam. ex DC.	Fabaceae	3		0.02	
Ficus sycomorus	Moraceae	3	16	0.37	1.35
Schefflera abyssinica Harms	Araliaceae	3	14	0.36	3.51
Olea welwitschii Gilg & G.Schellenb.	Oleaceae		60		6.52
Ilex mitis Radlk.	Aquafoliaceae		38		0.72
Olea capensis	Oleaceae		26		0.09
Pouteria adolfi-friederici	Sapotaceae		24		1.82
Cassipourea malosana	Rhizophoraceae		34		0.01

Celtis africana	Ulmaceae	14	3.51
Oxyanthus spaceous	Rubiaceae	66	0.14
Sapium ellipticum Pax	Euphorbiaceae	10	2.24
Mimusops kummel Bruce ex A.DC.	Sapotaceae	4	0.43
Polyscias fulva (Hiern) Harms	Araliaceae	4	0.77
Afrocarpus falcatus	Podocarpaceae	4	0.01

In both localities there is no practice of intercropping in the coffee farms but in Garuke, certain tree species are preserved as a potential timber tree or other construction purposes. Species commonly found in the coffee forests for this purpose includes *Cordia africana* and *Prunus africana*. None of the farmers in both localities reported use of inorganic fertilizers and only 20% of the farmers from Garuke area reported use of improved coffee varieties distributed by development extension workers.

Shade tree inventory

Twelve shade tree species were recorded within the Garuke coffee forest fragments with a total abundance of 243 individuals/ha. About 70% of the abundance was contributed by only four canopy tree species. The most common species were *Albizia gummifera* and *A. schimperiana* (Fabaceae), *Croton macrostachyus* (Euphorbiaceae) and *Millettia ferruginea* (Fabaceae) (Table 6).

But in Gera coffee forests the coffee shade layer comprises 22 tree species with an abundance of 526 individuals/ha, more than double of the richness and abundance recorded in Garuke fragments (Table 6). The shade tree abundance in the Gera forest was not dominated by a few tree species as in the case of the Garuke forest fragments. Except *Syzygium guineense* no species contributed more than 10% of the total shade tree abundance. Only three species, *Olea welwitschii*, *Syzygium guineense* and *Schefflera abyssinica* contributed more than 50% of the basal area.

In the Gera area, even though they cited *Albizia* and *Acacia* as suitable shade trees, this preference is not visible in the current forest composition, as evidenced by the presence of more than 22 tree species as shade trees and *Albizia* sp and *Acacia* sp represent less than 2% of shade tree abundance in the coffee farm.

DISCUSSION

This study explored farmers' criteria for selecting shade trees in Ethiopian traditional coffee management systems in Afromontane moist forests in Jimma Zone, Southwest Ethiopia**.** Farmers' decision on shade tree selection criteria and management of coffee shade trees were related to their knowledge on tree phenology and structure such as leaf deciduousness, leaf size, crown width and tree height, all related to mediating the micro-climate inside the forest. This corroborates with the management motivations described by Soto-Pinto et al. (2007) for Mexico as "by lowering temperature and controlling light penetration to get a cool air".

Most of the tree attributes considered favorable as a coffee shade tree by farmers of the study area are similar to what was reported in some Latin American countries (e.g. Albetin and Nair 2004; Soto-Pinto et al. 2007), even though there are also some differences. Regarding life span of leaves for example, the farmers in our study area preferred deciduous trees which shed their leaves such as *Albizia* and *Acacia* spp. The motivation is that they do not compete for water as compared to *Syzygium,* which remains with green leaves throughout the year. But Albertin and Nair (2004) reported that the majority of farmers in Nicoya Peninsula, Costa Rica, preferred evergreen trees capable of providing shade throughout the year. All the preferred shade tree species in our study area belong to Fabaceae family and are believed to have capacity of nitrogen fixing (Beer et al. 1998), contributing to the improved soil fertility reported by farmers.

There was also a difference in coffee shade tree management and selection between the two studied localities. In Gera, a large close-to-natural forest where forest coffee system was practiced for long period of time, selection criteria form a combination of reducing the canopy shade and other economic and ecological services generated from the shade trees, notably honey production in the forest, which is the second major source of income for the local people. Some big trees are retained in the coffee forests in Gera area either to install traditional beehives or for their large flower production. Big trees such as *Schefflera abyssinica* and *Syzygium guineense* are found dominantly in these managed forests for their flowers and are preferred for honey production, though they are not suitable shade trees for coffee. This shows a trade-off between honey production and coffee cultivation in the Gera area, which governs the coffee shade tree selection, as opposed to the Garuke area, where shade management is solely for coffee production, as honey production is a marginal activity.

Even though Farmers in Gera mentioned *Albizia* and *Acacia* as preferred shade trees and cited increased coffee productivity under their shade, these species were found in small percentages in the forests (Table 6). The preferred shade tree attributes mentioned and the tree species associated to these attributes (Table 3) were also in contrary to what is observable in the field (Table 6). The demarcation of the Gera forest as one of the National Forest Priority Areas (EFAP, 1994) may also preventing coffee management intensification in the area. Besides the population density in Garuke area is much greater (308 person/km^2) as compared to the Gera area (60 person/km^2) (http://www.oromiyaa.com/english/), which coupled with rapid population growth may have contributed to intensification of coffee management in the area due to shortage of farmland.

The shade trees in Gera area are more complex and are stratified but in Garuke, it shows a trend of homogenization both in height and composition (Table 6). In addition to coffee management intensification, the high population density in the Garuke area might have forced the farmers to remove most of the non-preferred shade trees for construction and firewood.

Some of the information reported by the farmers was not consistent with the actual facts in the farms. For instance only 20% of the farmers in Garuke area reported of planting improved coffee seedling varieties in their farms, but genetic study in the area revealed high similarity of SFC populations to the introduced CBD-resistant genotypes (Aerts et al. 2013). This may happen because of the complex coffee cultivation activities in the area, whereby farmers may plant seedlings spontaneously regenerating under the mother tree of the improved variety without knowing its source or the

wild varieties may be pollinated by pollens from the improved varieties. Similarly all respondents cited *Acacia abyssinica* as a most preferred shade tree but in practice it comprises only about 2.5% of the total abundance of shade trees in Garuke as compared to *Croton macrostachyus* (20%), which was reported as less preferred tree. The most abundant shade trees in Gera (Table 6) do not have the reported traits to be considered as preferred coffee shade.
The coffee production practices in the area can be considered as organic, since they do not apply inorganic fertilizers in their coffee farms and hence can benefit from organic coffee certification, which enables them to get premiums for their products.

Iimplications for management
The repeated removal of seedlings and saplings of canopy shade trees during coffee management through slashing has a negative consequence on the regeneration of preferred shade trees and jeopardized the sustainability of coffee production. In SPC systems, the dependence on few selected shade trees has a huge impact on forest biodiversity and consequently on ecosystem services generated from the forests. To this end, assisted regeneration of shade trees through small exclosures from which healthy seedlings and saplings will be selected to replace the old and dying canopy trees has to be implemented. This assisted regeneration is a key opportunity for canopy tree species choice, where a choice can be recommended to add a certain percentage of higher canopy trees for other ecosystem services such as apiculture than just coffee. The impact of the reported shade trees in improving coffee productivity and cup quality has to be scientifically proved to recommend the practice to other areas.

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