ORGANIC MATERIAL

SOCIOECONOMIC BENEFITS OF SHADE TREES IN COFFEE PRODUCTION SYSTEMS IN BONGA AND YAYU-HURUMU DISTRICTS, SOUTHWESTERN ETHIOPIA: FARMERS' PERCEPTIONS

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ABSTRACT

Coffea Arabica is extensively cultivated by households under a variety of shade trees in southwestern Ethiopia. The main purpose of this study was to assess the overall farmers' perception on the benefits of shade trees in coffee production systems in southwestern part of Ethiopia. Semistructured questionnaires were administered to 100 smallscale coffee farmers. In-depth interviews were also made with 10 selected farmers from Bonga and Yayu-Hurumu districts study sites. Farmers' perspectives were mostly comparable to the documented scientific facts with some noticeable differences. Among shade tree species legumes such as Albizia gummifera, Acacia abyssinica, Millettia ferruginea were highly favoured in that order. A significant number of the study subjects expressed an interest in the further propagation of the seedlings of the most favoured shade trees such as Albizia gummifera (95%), Acacia abyssinica (65%), Millettia ferruginea (55%) and Cordia africana (50%). The respondents strongly stated the serious problems associated with growing coffee without shade tree plants that included stunted growth which ultimately resulted in coffee yield reduction (97.3%) and quick wilting of coffee plants (93.6%). The majority of the respondents hassled other benefits of coffee shade trees such as firewood (96.4%) and honey production (92.7%) followed by improvement of soil fertility (79.1%) and reduction of soil erosion (78.2%). A significant number of farmers (39.1%) expressed their long experience of retaining legumes like Desmodium species in their coffee plots during weeding or clearing. Higher return values and better coffee attributes were generally assigned to shaded coffee systems particularly those dominated by tree legumes. The respondents had excellent knowledge on socioeconomic benefits of shade tree species. However, organic training is believed to minimize knowledge gaps on certain complex and/or unobservable ecosystem processes in the shaded coffee systems to boost the confidence of the farmers in supplying green commodities of premium prices on sustainable basis.

Keywords: intercropping; leguminous plants; organic farming; shaded coffee systems

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INTRODUCTION

Coffea arabica L. belongs to family Rubiaceae. This species is predominantly self-pollinating (autogamous) and the only natural allotetraploid (2n=4x=44) in the genus *Coffea*. It is a perennial woody shrub with a dimorphic growth characteristic which consists of vertical (orthotropic) and horizontal (plagiotropic) branches. Arabica coffee is the most important source of foreign currency for many developing countries. Seventy per cent of the world's coffee is contributed by smallholders in developing countries who grow coffee mostly on farms of less than 5 hectares and intercrop coffee with other crops (Mohan and Love, 2004). The agriculture-based Ethiopian economy is highly dependent on *Coffea arabica* (Gole et.al., 2002). It plays a fundamental role both in the cultural and socio-economic life of the nation. Traditional shaded coffee is cultivated principally by smallscale growers (95%) under rain-fed and low input production systems making the shaded Ethiopian coffee production naturally 'organic' (Petit, 2007). The present investigation put special emphasis on this type of production system that protects the environment and maintains biodiversity due to shade tree species.

Cultivation of coffee involves planting of young coffee plants in the understorey of a remaining native tree cover which principally includes *Acacia abyssinica*, *Albizia gummifera*, *Cordia africana*, *Croton macrostachyus*, *Ficus sur*, *F. vasta*, *Millettia ferruginea* and others (FAO, 1968; Taye, 2001). Further, in southwestern Ethiopia, natural forests are also common where *Coffea arabica* grows as understorey plant (Gole, 2003).

The effect of shade trees on Arabica coffee production has been debated for a long time and the general belief is that the advantages outweigh the felt negative impacts (Beer, 1987; Beer et al., 1998; Muschler, 2001). The favorable considerations for shade trees encompass temperature regulation, suppression of the major weeds of coffee, cheaper production, reduction of hail damage and better growth under high altitude conditions (Beer et al., 1998), as well as maintenance of biodiversity (Perfecto et al., 1996). The roles of shade trees in contribution of massive organic matter and lessening of soil erosion are also well addressed (Beer et al., 1998).

Furthermore, most common coffee shade trees are also acknowledged for their good capacity in formation of symbiotic associations with certain soil bacteria, rhizobia (Grossman et al., 2006) and arbuscular mycorrhizal fungi (Wubet et al., 2003) all of which play a pivotal role in improvement of soil fertility and boosting of yields of associated crops. Additionally, Muschler (2001) has verified the main benefits obtained from shading in terms of improved coffee attributes compared to unshaded ones.

Farmers in southwestern part of Ethiopia, have life long experience in growing coffee under various types of shade trees (FAO, 1968) which comply with the contemporary rekindled interest in organically grown coffee products. In addition, shaded systems promote viable and sustainable economic alternatives where the farmers can find possibilities for diversifications. Apart from contribution to understorey coffee bushes, farmers derive incalculable benefits from shade trees (FAO, 1968; Beer et al., 1998; Hailu et al., 2000; Peeters et al., 2003). Shade tree species such as *Croton macrostachyus* (Giday, 2001), *Albizia gummifera* and

Syzygium guineense (Geyid et al., 2005) play a vital role in traditional medicine to combat various infectious diseases. Another added advantage of shaded coffee systems is the increasing demand and willingness of consumers to pay premium prices for ecological and fair coffee (Wikström, 2003; van der Vossen, 2005). Smallholder coffee producers obtain supplementary advantages from diversification/intercropping farming method to promote the household economy (Albetin and Nair 2004; Bentley et al., 200; Reddy et al. 2004). The authors strongly stressed the multifaceted advantage of intercropping compared to planting a single crop. Furthermore, in coffee forests, Philpott (2005) and Philpott et al. (2006) have demonstrated the remarkable importance of ants (*Azteca* species) in coffee production systems.

In Ethiopia, information on socioeconomic benefits of shade tree species is scanty. Hailu et al (2000), however, have reported a wide array of advantages why farmers retain *Millettia* trees on their farmlands. This study was conducted to 1) identify the most important shade tree species from farmers' point of view, 2) document farmers traditional knowledge on socioeconomic benefits of various shade trees in coffee production systems, 3) document the uses of some legumes intercropping and ants in coffee forests.

MATERIALS AND METHODS

Description of the study sites

The study was executed from June to December 2007 in Southwestern Ethiopia. The study sites included Bonga district (Kaffa Zone) in Southern Nations, Nationalities and Peoples' Regional State (S.N.N.P.R.S) and Yayu district (Illubabor Zone) in Oromia Regional State, Ethiopia. The study sites are located between 07°28'-08°28' North latitude and 35°50'-36°45' East longitude. The altitudes in the study sites range from 1376-1890 masl. Average diurnal and seasonal fluctuations in temperature range from 14 to 30°C and relative humidity ranges from 43 to 85%. Heavy rainfalls (1000 to 2000 mm) are very frequent. Rain falls mainly from June to August and its distribution is bimodal (Gemechu, 1977). The size of the investigated coffee systems ranged from 0-22 ha (forest coffee) and 0-4.5 ha (nonforest coffee). Most farmers possess both forest and nonforest coffee plots. Some farmers had either forest or nonforest coffee plots only. Nonforest coffee includes agroforestry (either on fields or on farmlands) and unshaded coffee systems. Coffee plants on non-cultivated plots are considered as coffee plants on fields but those coffee plants under shade that were either intercropped or where lands were tilled outside the canopy are considered as coffee plants on farmlands. Normally the latter two are found close to homestead areas. Herbarium specimens were collected for coffee shade trees as well as other plants species and identified accordingly (Hedberg et al., 2003).

Sites and farmers selection for the study

The authors collected the required information through 37 closed and open ended questions and semi-structured interviews in two coffee producing communities, Kaya Kella ***Kebele***, Bonga and Elemmo ***Kebele***, Yayu Hurumu districts. ***Kebele*** refers to the smallest administrative cell embracing the average 350-500 household heads according to the administration policy of the country. Native languages in the two study areas are respectively the Kaffa and Oromo. Interviews in Kaffa language were conducted using a translator. The study sites were chosen on the basis of 1) presence of natural coffee forests and agroforestry based coffee production systems and 2) accessibility of the focal sites to transportation.

Respondents were selected on the basis of the following major parameters: 1) long experience and knowledge of growing coffee under key shade tree species (at least five years), 2) size of plot (at least 0.5 ha of either natural coffee forest or shade grown non-forest coffee), 3) the person interviewed falls into the category of either male or female household head and 4) willingness to participate in the investigation. To get material information for the set criteria, the authors worked with village leaders and the local development agents.

Together with village leaders and development agents, ten (five from each site) household heads who had rich experience on managing both forest and nonforest coffee were chosen among the 110 for detailed interviews. During the 60-150 minutes interviews consisting of a basic framework of questions, farmers freely discussed the reasons why they grow coffee plants under shade and overall prevailing situations in shaded coffee systems. In addition, responses were collected from 100 (50 from each site) farmers using questionnaires. In case, a particular farmer was unable to read and write (illiterates and those who did not attend at least junior secondary school), their responses were carefully marked and recorded by the authors and research assistants in the respective study areas. The collected information included 1) demographic and basic farm data, 2) shade trees and overall uses, 3) shade trees/legume herb and soil fertility, 4) shade tree management, 5) intercropping, 6) possible importance of ants (*Azteca* species) and 7) other uses of coffee. Doubtful questions were corrected using prompt pilot study technique. An effort was made to include women respondents in the study, but the fact that most respondents were men was an obvious constraint which is attributed to the local tradition of land ownership which was mostly handled by male respondents.

DATA ANALYSIS

All data were analyzed using SPSS Version 13. Responses involving open ended questions were classed into categories and analyzed accordingly using the same statistical package.

RESULTS

Respondents' demographic and basic farm data

Of the one hundred ten respondents considered in this study, only 8.2% were females. The ages of household heads ranged from 22-80 years (data not shown). The respondents education levels were: illiterate, 27 (24.5%), those with adult education, 17 (15.5%), grade 1-6, 44 (40%), grade 7-8, 12 (10.9%) and those who attended their senior secondary school, 10 (9.1%).

Ninety seven percent of the farmers owned forest coffee (data not shown). The main income sources for the household heads included coffee (29.1 %), noncoffee crops (1.8%) or both (69.1%). Total annual farmers' net income ranged from 110-7000 Ethiopian Birr (1 USD=16.56340 EthB). Total annual income and ages of household heads were not correlated ($r=-0.036$, $p=0.704$) and neither to respondents' education level ($r=0.036$, $p=0.706$) nor plot size for non-forest coffee ($r=0.16$, $p=0.095$). However, total annual income was positively correlated to plot size for forest coffee ($r=0.639$, $p=0.001$). Other noncoffee crops cultivated were mainly cereal crops (77.3%). For all respondents, labour force for coffee production was supplied by respective family members.

Shade trees and farmers' perspectives

Over seventy four percent of the interviewees had more than 10 years of experience in growing coffee under shade trees. Most respondents (70.9%) mentioned that the shade trees were older than 30 years (Table 1).

Table 1. Age of shade trees and respondents' age category, southwestern Ethiopia

Age of shade tree	**Respondents' age category**						**Total**
	20-30	31-40	41-50	51-60	61-70	71-80	
Less than 15 years	2	-	2	3	-	-	7
Between 20-30 years	7	10	2	2	4	-	25
Above 30 years	17	19	21	9	5	7	78
Total	26	29	25	14	9	7	110

Over 86% of the farmers preferred 50% of light penetration for maximum harvest. None of the farmers preferred either complete full shade or 100% light penetration. The majority of the farmers (95%) mentioned dry and sunny seasons as critical times of shading coffee plants (data not shown). The interviewees cited the requirement of shading at all developmental stages of coffee plants with different frequencies, i.e., at seedling stage (91.8%), at sapling (76.4%), at adult (70%), at flowering (74.5%) and at fruiting (74.5%).

Among common shade tree species, *A. gummifera* (98.2%), *A. abyssinica* (64.5%), *M. ferruginea* (52.7%), *V. amygdalina* (49.2%) and *C. africana* (45.5%) were cited by interviewed farmers to be included in their plots (Table 2). None of the farmers at Bonga and Yayu study sites stated *A. grandibracteata* or *E. brucei* as common shade tree plants (data not shown). Most farmers cited *M. ferruginea*, *C. africana* and *C. macrostachyus* at Bonga district but *A. abyssinica* at Yayu (data not shown). Farmers' overall perception of these four shade tree species was highly impressive. Some of the principal reasons were 1) possession of thin and easily decomposable leaves by the first three (72.7%), 2) most of the time they are green (68.2%), possession of several branches (66.4%), 3) they do not cause stunted coffee growth (66.4%), 4) there is better coffee yield under them (66.4%) and 5) they are not too tall (56.4%).

Table 2. Some tree species commonly used for shading coffee plants in farmers' fields/farms /forests, Southwestern Ethiopia

Scientific name	Family	Total frequency (%)
Albizia gummifera	Fabaceae	108 (98.2)
Acacia abyssinica	Fabaceae	71 (64.5)
Millettia ferruginea	Fabaceae	58 (52.7)
Vernonia amygdalina	Asteraceae	54 (49.2)
Cordia africana	Boraginaceae	50 (45.5)
Sesbania sesban	Fabaceae	40 (36.4)
Albizia grandibracteata	Fabaceae	36 (32.7)
Croton macrostachyus	Euphorbiaceae	30 (27.3)
Erythrina brucei	Fabaceae	25 (22.7)
Ficus vasta	Moraceae	22 (20.3)
Schefflera abyssinica	Araiaceae	11 (10.0)

The majority of the farmers expressed an interest in the further propagation of the seedlings of *A. gummifera*, *A. abyssinica*, *M. ferruginea* and *C. africana* in that order for wide spread usage in their farms/fields because of their good features as shade tree species (Fig. 1).

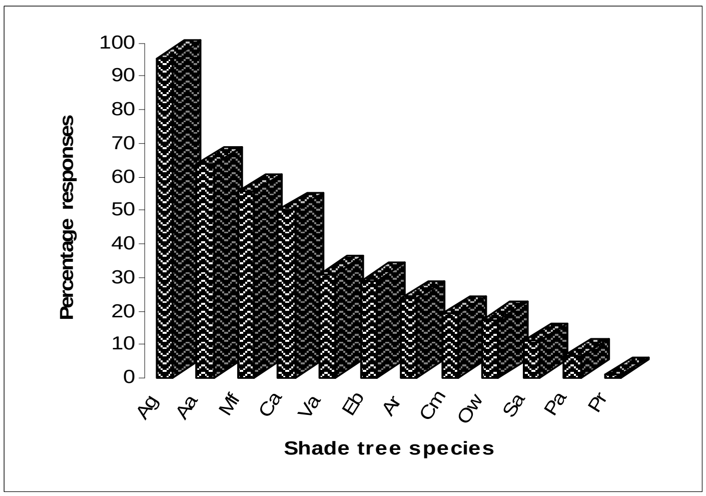

Figure 1. Responses of farmers for the best coffee shade tree species propagation for wide spread usage in their respective plots, Southwestern Ethiopia. Abbreviations: Ag= *Albizia gummifera*, Aa= *Acacia abyssinica*, Mf= *Millettia ferruginea*, Ca= *Cordia africana*, Va= *Vernonia amygdalina*, Eb= *Erythrina brucei*, Ar= *Albizia grandibracteata*, Cm= *Croton macrostachyus*, Ow= *Olea welwitchii*, Sa= *Schefflera abyssinica*, Pa= *Prunus africana* and Pr= *Phoenix reclinata*.

Characteristic features of shade and sun grown coffee are presented in Table 3. All interviewed farmers (100%) stated that higher coffee yield could be obtained when shaded. The majority of the respondents (69.1-99.1%) assigned better qualities to shaded coffee systems (Table 3). Over eighty five percent of the respondents mentioned prematurity and demand of more management as typical features for sun grown coffee plants (Table 3).

Table 3. Salient features of shade and sun grown coffee mentioned by the household heads, Southwestern Ethiopia

Characteristics	Frequency (%)	
	Shade grown	Sungrown
Higher coffee yield	110 (100)	0 (0)
Bigger and heavier coffee beans	109 (99.1)	1 (0.9)
More coffee stems	108 (98.2)	2 (1.8)
Coffee beans with better taste	103 (93.6)	7 (6.4)
Better looking green and roasted coffee beans	101 (91.8)	9 (8.2)
Coffee stems with more branches	100 (90.9)	10 (9.1)
Stronger coffee stems	76 (69.1)	34 (30.9)
Demanding more management	16 (14.5)	94 (85.5)
Early maturity of coffee beans	16 (14.5)	94 (85.5)

Growing coffee plants without shade

The farmers strongly stated serious problems associated with growing coffee without shade tree plants, *i.e*., 1) stunted growth which ultimately resulted in coffee yield reduction (97.3%), 2) quick wilting of coffee plants (93.6%), 3) bean size reduction (89.1%), 4) increases in weed problems (85.5%), 5) increase in unfavorable effect of heavy rain and hail damage which pose withering/dropping of flowers (80.9%), 6) increases in frost damage (70.9%), 7) increases in soil erosion (52.7%), 8) exhaustion of soil fertility due to lack of fertilizers “shade tree leaves“ (1.8%) and 9) coffee leaves go easily yellow/red (1.8%)(data not shown).

Other benefits of shade tree species

The majority of the respondents stressed other principal benefits of coffee shade trees, e.g., firewood (96.4%) and honey production (92.7%) apart from shade provision to coffee plants (Table 4). More than eighty six percent of the respondents cited that coffee plants get benefits from shade trees for nutrient acquisition and soil moisture improvement (79.1%) which was mainly linked to leaves of shade trees (data not shown). Many farmers (69.1%) accordingly expressed the presence of soil fertility difference between shaded and unshaded coffee plants where they strongly favored the former production system.

Table 4. Other socioeconomic benefits of coffee shade tree species alluded by the respondents, Southwestern Ethiopia

Mentioned benefits	Responses (%)	
	Yes	No
Firewood	106 (96.4)	4 (3.6)
Honey production/beekeeping	102 (92.7)	8 (7.3)
Improvement of soil fertility	87 (79.1)	23 (20.9)
Reduction of soil erosion	86 (78.2)	24 (21.8)
Reduction of hail/frost damage	65 (59.1)	45 (40.9)
Medicinal value	63 (57.3)	47 (42.7)
Timber production	63 (57.3)	47 (42.7)
Biodiversity conservation	62 (56.4)	48 (43.6)
Reduction of agrochemical inputs	55 (50)	55 (50)

Other benefits of coffee plants

Many farmers stated the benefits they obtain from coffee plants other than for drinking and main income source which embodied firewood (85.5%), construction/fence (75.5%) and medicinal value (72.7%).

Use of legumes for soil fertility

About 39.1% farmers expressed their long experience of retaining legumes like *Desmodium* species in their coffee plots during weeding or clearing. There was a significant difference ($p < 0.05$) between study sites and *Desmodium* species retention. For instance, over twenty three percent of farmers at Bonga site but only sixteen percent of Yayu district farmers retained *Desmodium*. The respondents stated the main merits of retaining *Desmodium* to include soil fertility improvement (30%), weed reduction (28.2%) and discouraging of coffee parasitic worms (23.6%).

Almost all the respondents expressed their rich experience of adding different decaying organic materials and dropped leaves beneath coffee plants. Many respondents stated that the best sources of this experience were mainly own practice (68.2%) and elderly farmers (60.9%; Fig. 2). Almost all farmers also underscored the importance of researchers (local and foreign) and workshop/seminar in disseminating information on use of adding decaying organic materials under the coffee plants (Fig. 2).

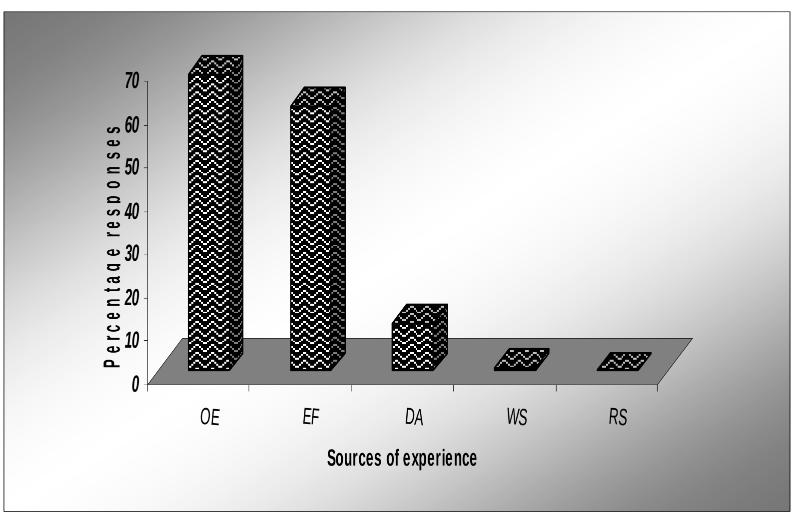

Figure 2. Sources of experience in adding different decaying organic materials and dropped leaves beneath coffee plants, Southwestern Ethiopia. Abbreviations: OE= own experience, EF= elderly farmers, DA=development agents, WS= workshop/seminar, and RS= researchers.

The majority of the interviewees (98.2%) preferred thin and small leaves in decreasing the intensity of soil erosion. The same percent of respondents stated that broader and larger leaves increase soil erosion. The farmers mentioned different means of preventing soil erosion from their coffee plants at sloppy places. These embodied planting trees, *Musa paradisica*, *Ensete ventricosum* and grasses (22.7%), making terraces (10%) or using both methods (67.3%).

Coffee and shade tree management

Most farmers (76.4%) mentioned the replacement of shade trees when the original is cut or dead. The interviewees used to replace the original type species (68.2%). The respondents (74.5%) chose the species that replaces the original one on the basis of its suitability for coffee plants (fast growth, longevity, possession of thin and small leaves and the like). Most farmers (89.1%) were not comfortable about choosing evergreen trees for shading coffee plants. The cited principal reasons included improper light penetration (85.3%) and soil fertility problems (88.9%) because they strongly felt that leaves which regularly drop from shade trees are the best source of fertilizer for coffee plants. Some (18.2%) also prune the shade trees that damped under coffee plants.

Over seventy four percent of the farmers had no experience of applying agrochemicals including herb- and pesticides. The interviewed household heads stated some basic reasons for not applying agrochemicals which embodied 1) lack of previous experience (30%), 2) coffee plants get essential nutrients from shade trees (dropping of leaves, 18.2%) and 3) economic reasons (4.5%).

Intercropping

The commonly intercropped spice was *Afromomum korrorimum* (75.5%), *Piper capense* (46.4%) and *Zingiber officinale* (6.4%). The farmers also incorporated other cereal crops like *Zea mays* (23.6%), *Sorghum bicolor* (6.4%) and legumes such as *Vicia faba* (16.4%) and *Phaseolus* spp. (16.4%). The intercropping with *Musa paradisica* (26.4%) was either because it acts itself as a shade 'tree' (Fig. 3a) or done under taller shade trees (Fig. 3b) around homestead areas.

a

b

Figure 3. Coffee intercropping practices, Southwestern Ethiopia (a) intercropping of banana with coffee plants in the absence of shade tree species, (b) intercropping of banana with coffee bushes under the shade tree species, *Ficus sur*. Note 1) these systems of cultivation are common around homestead areas. The purpose is multidirectional, i.e., shade and fruit provision as well as soil erosion control. 2) bananas are planted on direction of erosion on sloppy areas for the latter use due to its good root system for the purpose.

Roles of ants (Azteca species) in coffee forests

The notable importance of ants (*Azteca* species) in natural coffee forests was mentioned by more than half of the interviewed farmers (69.1%), in controlling red coffee berries boring insects and other pests (67.3%) added to control of young pigs, monkeys, apes and snakes (25.5%).

DISCUSSION

The interviewed farmers had long experience in growing coffee bushes under shade tree species. Their overall impression of shade was quite positive and they considered shade as a prerequisite for coffee production systems. The majority of the farmers preferred moderate shade conditions which is also considered favourable for good coffee growth since photosynthetic rates of coffee are generally at a maximum at intermediate shade levels in the tropics (Beer et al., 1998). Similar to coffee growers in Costa Rica (Albertin and Nair, 2004), the respondents felt that moderate light is necessary for fruit filling and discouraging some coffee diseases but full light penetration poses coffee wilting. The farmers strongly stressed the necessity of shading coffee bushes (at all developmental stages) in general and seedlings, in particular, especially during dry and sunny seasons (December to April). The principal reasons mentioned included protection from high heat, strong sun and wind all of which cause evaporation of accumulated water (Beer, 1987; Beer et al., 1998).

The species diversity of common coffee shade trees (n=11) repeatedly mentioned by the interviewed farmers seemed very few as compared to the previous studies conducted in traditional coffee cultivation in Costa Rica (Albertin and Nair, 2004). In this investigation, farmers gave special emphasis to those shade trees which they mainly retained on their fields/farmlands for their favourable characteristics and other uses.

The remarkable differences between the two study areas with respect to some (legumes) shade tree species frequencies are attributed to their abundance and distribution in those particular localities (data not shown) as observed elsewhere (Babbar and Zak, 1995) because leguminous tree species used to shade coffee vary by region. For instance, *M. ferruginea* and *A. abyssinica* are highly important shade tree species to Bonga and Yayu district farmers, respectively. Muschler (2001) reported *Erythrina poeppigiana* as a suitable tree to provide shade and mulch to coffee plantations in the Atlantic Zone of Costa Rica.

Most interviewed farmers cited *A. gummifera*, *A. abyssinica*, *M. ferruginea*, *V. amygdalina* and *C. africana* in that order as the best coffee shade tree species to have in their plots. The first three are commonly mentioned by all farmers as “father of coffee”. Similarly, leguminous plants are the most preferred trees among coffee growers across the globe (Beer, 1987; Grossman, 2003; Albertin and Nair, 2004). Some of the characteristics considered favorable by farmers for the legume shade tree species were increase in soil organic matter (Beer, 1998; Grossman, 2003; Albertin and Nair, 2004), rapid decomposition of legumes (Grossman, 2003), ability of leaf litter to control soil temperature (Grossman et al., 2006), guarding against soil moisture loss and erosion and better growth and yield of crops under them (Beer, 1998). In Mexico, studies revealed that an organic farmer claims that *Inga* shade improves coffee plant health (Grossman, 2003). Similarly, in Costa Rica, 96% of farmers commonly mentioned legume shade trees like *Inga* species as unsurpassed shade trees to include in their coffee fields (Albertin and Nair, 2004).

Native leguminous tree species are often used to supply all or a portion of the Nitrogen needs of coffee bushes (Soto-Pinto et al., 2000). The use of nitrogen-fixing trees for improvement of associated crop production is fundamental to low-input sustainable agricultural practices in most developing countries (Sprent and Parsons, 2000). Contribution of biologically fixed Nitrogen, specifically to coffee systems by legumes in different coffee growing countries has been well reviewed (Grossman et al., 2006 and references therein). Nevertheless, none of the interviewed farmers cited the role of microorganisms (rhizobia, decomposers and others) in maintenance of soil fertility. Further, the interviewees did not have a clear idea about nitrogen-fixing and non-nitrogen-fixing shade trees. Farmers preferred the leguminous shade trees mostly from their day to day observations, i.e., their suitability for coffee production purposes. The respondents mostly associated the helpful roles of coffee shade trees with their leaves for incorporation of quality organic matter and shade provision as well as roots for storing water. The stated favourable features of leguminous shade trees such as *A. gummifera*, *A. abyssinica* and *M. ferruginea* made them the top excellent candidate for further propagation on large scale. Further, the respondents strongly harassed the propagation of *V. amygdalina* and *C. africana* for shade provision and other uses. For instance, *C. africana* is one of the known top woody plants for quality timber extraction in the country.

Farmers considered tree height as one of the characteristics favorable for shading coffee bushes (cf. Albertin and Nair, 2004). The interviewees did not favor highly emergent (too tall) shade trees particularly those with few branches, because the shading effect is being reduced and coffee bushes could be exposed to strong sun during extended dry season. The other unfavourable feature of too tall shade trees mentioned was damage caused to coffee plants when a branch or twigs break from shade trees by monkeys and other arboreal animals as well as high speed wind especially during coffee flowering and fruiting stages. Beer (1987) strongly stressed the damage caused to coffee plants by branch/stem breakage.

All the interviewed farmers stated that higher coffee yield could be obtained when shaded. This observation contradicts with what has been stated in the literature (Beer, et al., 1998; Faminow and Rodriguez, 2001), i.e., unshaded systems produce greater coffee yields. However, these authors did not deny the typical feature of unshaded coffee system that suffers from diminishing returns as the coffee plants grow older. Additionally, they indicated that coffee plants in shaded systems enjoy greater longevity and even more annual yields unlike high and low yield years under full sun grown coffee plants. Such more consistent yields in shaded systems due to increased productive life of the coffee plants can make planning easier (Beer, 1987; Faminow and Rodriguez, 2001). Thus these latter ideas could strongly support the farmers' critical observation of more annual harvests under shaded systems as compared to unpredictable yields of sun grown systems.

Some of the characteristic features mentioned for shade grown coffee were found also in the literature (Muschler, 2001). The majority of the farmers (Table 3) mentioned coffee stems with more number of branches (90.9%) and stronger coffee stems (69.1%) as some of the salient features of shaded coffee systems. Nevertheless, Ricci et al. (2006) have indicated that shading reduces the number of branches, plant diameter and nodes (farmers did not mention). This observation could be associated with differences in analytical observation between the scientific community and farmers. Ninety four percent of the interviewees (Table 3) assigned demand for more management and prematurity of coffee beans to unshaded coffee plants. The requirement of greater inputs of materials and labour by unshaded coffee system are known main disadvantages (Faminow and Rodriguez, 2001).

The majority of the farmers frequently expressed the far reaching problems of growing coffee without shade by emphasizing stunted growth (97.3%) and short life span (93.6%) of coffee bushes as major disadvantages. Albertin and Nair (2004) have also mentioned that coffee plants have a shorter life span when grown under full sun, and a lack of trees would result in increased soil erosion. Several of the problems that respondents stated with regard to growing coffee plants with no shade are mentioned by Beer (1987), Beer et al. (1998), Faminow and Rodriguez (2001) and Muschler (2001).

The majority of the interviewed farmers (Table 4) singled out other desirable benefits derived from shaded systems.

Some of the mentioned advantages such as wood, honey, timber, and medicinal importance have high commercial values added to reduction in agrochemical inputs under shaded systems. Hence these and other mentioned benefits (Table 4) may serve as a life hedge against coffee crop failure, or a drop in coffee price (Beer et al., 1998; Peeters et al., 2003).

Apart from shade provision to coffee bushes, farmers strongly underlined that one of the principal reasons of using shade tree is incorporation of organic matter to coffee production systems. As farmers expressed promptly, the contribution of massive amounts of organic matter to shaded coffee systems is well documented (Beer, 1987; Beer et al., 1998; Faminow and Rodriguez, 2001). Moreover, cacao farmers in Ecuador (Bentley et al, 2004) have also mentioned that shade trees improve soil fertility and help to maintain soil moisture for extended period of time which gives immense advantage to understorey crops like cacao and coffee.

Farmers, who had long experience of retaining legumes like *Desmodium* species in their coffee plots, stressed some functions related to soil fertility and suppressions of weeds and parasitic worms. However, in case of worm suppression, farmers did not know explicitly how. For instance, coffee parasitic nematodes are very tiny and invisible to the naked eyes. The farmers associate rather the absence of defects and sign of disease as well as worms on coffee roots wherever there is more *Desmodium* species as suppression mechanisms. Information in the literature lists corroborates to some of the farmers' observations on use of *Desmodium* species in coffee plots. Snoeck et al (2000) for instance, demonstrated that nearly 30% of the nitrogen fixed by legumes like *Desmodium* and *Leucaena* was transferred to associated coffee trees. Apart from nitrogen fixation, *Desmodium* species play pivotal roles in suppression of parasitic nematodes (Herrera and Marban-Mendoza, 1999) and control of weeds (Bradshaw and Lanini, 1995) in coffee plantations.

Farmers had excellent understanding about the fundamental advantages of depositing different decaying organic materials beneath coffee bushes mainly from their own experiences and elderly farmers. Farmers' knowledge on organic amendments to improve soil fertility and then the growth of plants has been widely documented (Grossman, 2003 and references therein). Nevertheless, researchers and workshops/seminars had hardly played a significant role in disseminating information on use of such eco-friendly soil improving substances.

Almost all the respondents had a good acuity of the effect of leaf size with respect to soil erosion. As also mentioned by Beer (1987), farmers preferred thin and small leaves (possessed by the most favoured legume shade trees) compared to broader and bigger ones in decreasing the intensity of soil erosion. Considering a similar study in Costa Rica (Albertin and Nair, 2004), however, the majority of the farmers felt that leaf size was not an important characteristic to take into account, since it is so variable among trees. This could be attributed to differences in the most favoured shade trees (*Inga*, *Erythrina* and *Senna* species), Costa Rica versus *A. gummifera*, *A. abyssinica* and *M. ferruginea*, this study.

At sloppy places, the majority of the interviewed household heads use to plant *M. paradisica*, *C. papaya* and other suitable species on terraces to hold the soil firmly and reduce erosion (cf. Beer, 1987; Beer et al., 1998) with added advantage for alternative income sources with good returns.

Most farmers in the study sites expressed their rich experience in replacing cut or dead shade trees by the original type species. The characteristics that farmers considered for the species that replaces the original one embodied fast growth, longevity, deciduousness, possession of thin and small leaves which all are generalized as suitability for coffee plants growth. In general, since the shade trees (*A. gummifera*, *A. abyssinica* and *M. ferruginea*) that farmers favoured most comply with nearly all criteria set by Beer (1987) in choosing desirable characteristics for perennial crop shade trees, one cannot undervalue the respondents' criteria to choose the right replacement tree species.

The majority of the farmers who participated in this investigation preferred deciduous shade trees compared to evergreen ones. The respondents strongly felt the incalculable contribution of organic matter to coffee bushes via dropped leaves in bulk as the main added advantage besides farmers' great vacillation on evergreen trees for proper light penetration. Farmers' opinion in Costa Rica (Albertin and Nair, 2004), however, was in favour of evergreen shade tree species. This could be attributed to the nature of the most preferred shade tree, *Inga* because it is a non-deciduous genus (Peeters et al., 2003). These farmers claim that evergreen trees are absolutely needed during dry season, the time that coincides with dropping of leaves by deciduous trees. In both cases the forwarded reasons seemed convincing although the issue of ever greenness was not dealt with in detail (Beer, 1987). Of the suitable shade tree characteristics mentioned by Beer (1987), one simply states that if deciduous trees are used, it is preferable that they flush their leaves rapidly. It is so doubtful that all the features displayed by evergreen trees comply with those top 21 listed characteristics (Beer, 1987) of shade tree species. This is infact, a big knowledge gap to be bridged and addressed by further investigations on suitability of either deciduous or evergreen trees to provide proper shade to coffee bushes. Nevertheless, a review of the literature (Albertin and Nair, 2004) is in favour of deciduous shade trees for providing mulch to maintain soil moisture in areas of little rainfall.

Smallholder coffee producers also depend on other alternative means such as annual crops, spices, fruits and others to promote the household economy (Albetin and Nair 2004). The supplementary advantages of diversification have been well documented (Reddy et al. 2004) for avoidance of heavy dependence on a single product (coffee) which suffers either from yield failure or serious price fluctuation in the international markets. Farmers also incorporate some pulses like *V. faba* and *Phaseolus* spp. into their coffee plots. Intercropping with legumes could be a means to restore soil fertility in coffee production systems. Farmers perceived intercropping of *M. paradisica* as particular importance in terms of provision of shade, fruits and reduction of soil erosion (Fig. 4a and b). However, this kind of intercropping is not appreciated in the literature (Beer et al., 1998). The authors claim that damage could be caused to coffee and newly established permanent shade trees during harvest and/or windfall in addition to intensive competition of *M. paradisica* with coffee plants.

Most of the respondents were aware of the importance of ants in controlling coffee berries boring insects and other pests (Philpott, 2005). There are, however, several advantages of ants

(Philpott et al., 2006) not cited by the farmers in shaded coffee systems such as enhancement of pollination and floral protection. Additionally, the authors claim that ants have a great implication for biodiversity conservation. On the other hand, the interviewees repeatedly stated other benefits of ants in coffee forests for control of young mammal pests and snakes.

In traditional shaded coffee production systems, shade trees are perceived as a necessity by almost all interviewed farmers, principally to mitigate coffee bushes from the suboptimal climate and ensure sustainable production by contribution of massive litter. Leguminous shade trees and *C. africana* are highly favoured and there is a great need for further propagation of their seedlings on large scale. Shaded coffee systems are vastly favoured by the majority of the respondents due to higher yield and better coffee attributes. Farmers could derive a wide array of benefits from shaded systems which can alleviate weighty dependence on a single product, coffee, which may suffer from either production failure or sudden slump in prices in international markets. Moreover, the shaded systems can be viewed as a conservation-oriented cultivation strategy which complies with interest of global organic coffee consumers.

Farmers have an excellent knowledge of the socioeconomic benefits of coffee shade trees. They could state most of the facts in the way they are presented in the scientific literature. However, the respondents were deficient on some basic concepts in general and phenomena that they cannot see in particular as also mentioned by Grossman (2003) and Albertin and Nair (2004). Therefore, organic training on uses of legume plants and their association with beneficial soil microorganisms, involvement of microorganisms in organic matter transformation, roles of ants, and overall other interactions in natural coffee forests may enrich farmers' local ecological knowledge and build ample self-assurance about their critical observation and responses. Such training could augment sustainable production with reliable returns which is also environmentally friendly.

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