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SURVEY ON POTENTIALS AND CONSTRAINTS OF SHADE TREE SPECIES FOR ARABICA COFFEE PRODUCTION IN SOUTH ETHIOPIA

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Abstract: **A survey was conducted to collect information on potentials and constraints of shade tree species for Arabica coffee production in south Ethiopia in two woredas of sidama and Gedio zones. The main purpose of this study was to identify potentials and constraints of coffee shade trees widely grown/used by small scale coffee farmers in south Ethiopia; and to identify fast growing and ideal shade tree species for coffee production in the area. To address this tasks field and desk research was accompained by interviews and discussion with focus groups. Semi-structured questionnaires were administered to 240 small scale coffee farmers. Farmers' perspectives were mostly comparable to the documented scientific facts with some noticeable differences. Among shade tree species best compatible with coffee such as Millettia ferruginea, Cordia africana, Erythrina abyssinica and ficus sure were highly favored in that order. Some of the respondents strongly stated the serious problems associated with growing coffee with shade tree plants that included nutrient, water and sun light competition with coffee and creation favorable micro-environment for the occurrence of same coffee disease. The majority of the respondents hassle other benefits of coffee shade trees such as firewood (90%), Timber and construction value (74.2%), and honey production (43.8%) followed by other benefit like improvement of soil fertility and reduction of soil erosion (6.2%). Most of the respondents were cited that there is no problem related to shade trees. Additionally, most of the interviewees stated that there were great potential shade trees in the study area. The respondents had excellent knowledge on the potential and constraints of coffee shade trees. However, training on uses of different coffee shade trees, their manage mental practices, legume plants and their association with beneficial soil microorganisms, involvement of microorganisms in organic matter transformation, and overall other interactions of coffee with shade trees should be provide to farmers to enrich their local knowledge and build ample self assurance about their critical observation and responses. In general, the shade trees Millettia ferruginea, Cordia africana and Erythrina abyssinica are recommended for the study area.**

Keywords: **Arabica coffee; constraint; potential; shaded coffee; shade trees**

I. 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.

Coffee is shade-loving plant, which is naturally growing as an under-story shrub in its original ecology in the tropical high rain forests of south and south-western Ethiopia (Paulo's and Tesfaye, 2000). Besides; its wild and semi-domesticated phases in the complex natural forests of the country, the crop is extensively cultivated in traditionally managed gardens and in modern plantations under a variety of shade trees (Tesfaye, 1995; Yacob et al., 1996; Paulos and Tesfaye, 2000; Workafes and Kassu, 2000). Shade is more essential to Arabica coffee for the reasons that high light intensity, high temperature and low soil moisture affect the growth by reducing the leaf area, net photosynthesis and

extension growth and also induce over-bearing and 'Die-back' which refers to the death of young tertiary branches. Arabica coffee is very sensitive to high light intensity and high temperature resulting in the early senescence of leaves and defoliation. Shade trees have positive effects on microclimate and soil biological properties which are the key to long term sustainability of coffee eco system. 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.

Under tropical conditions, shade is very much essential to prevent over-bearing, suppress weed growth, reduce the intensity of sunlight and temperature, combat drought effects, to maintain the moisture levels in tissues and to protect the coffee plants from low temperature, wind velocities and damage caused by hail stone. Adequate shade improves soil fertility by way of returning large amounts of leaf litter to the underneath soil, nitrogen fixation and retains soil moisture. Shade limits the incidence of pest such as white stem borer and leaf rust disease in Arabica coffee. The incidence of white stem borer, which can cause death of plants, will be more in arabica coffee grown under less shaded condition. Similarly the incidence of leaf rust will be more in Arabica coffee grown in open condition compared to shaded condition. The shade was also found to improve the coffee quality.

Arabica coffee requires 50-60% of filtered shade for maintaining good consistent crop yield. The canopy of permanent shade trees has to be regulated by undertaking the operations such as shade lopping, shade thinning and shade lifting depending upon the necessity and requirement to maintain optimum shade for the coffee plants. Shade trees are therefore recommended as a protective measure when environmental conditions can be difficult for coffee, particularly in areas which are exposed to high temperature, long drought, heavy rain fall and chance of haill**.**

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).

Sidama and Gedeo Zones are the major coffee producing areas in the Southern region and coffee is grown as garden (cottage or smallholder) crop, intercropped with Enset (*Enset Ventricosum*) or under the evergreen shade trees of *Erythrina* Spp., *Milletia Ferruginea* and *Albezzia* Spp. (Tefestewold, 1995). Sidama and Yirgacheffe coffee types produced in these Zones possess unique quality, are largely preferred by arabica coffee consumers and fetch premium prices in the world market. But research study on the subject of potential and constranits coffee shade tree species in this area is scanty. Therefore, this study was conducted to 1) Identify constraints and potentials of coffee shade trees widely grown/used by small scale coffee farmers in south Ethiopia; and 2) To identify fast growing and ideal shade tree species for coffee production in the area.

II. MATERIALS AND METHODS

Description of the study sites

The study was executed in dry and wet season during 2013 in Sidama and Gedio zones. The study sites included Aleta wondo district from Sidama Zone and Wonago district from Gedio zone in Southern Nations, Nationalities and Peoples' Regional State (S.N.N.P.R.S). The study sites are located between 6^0 19'-6^0 36' N latitude and 38^0 15'-38^0 26' E longitude. The altitudes in the study sites range from 1800-1890 m asl. Average diurnal and seasonal fluctuation in T^0 range from 11 to 27^0C. The area has a bimodal rainfall pattern with average annual precipitation ranging from 1269-1342mm. The principal wet season lies in between the months of July and September and the subsidiary wet season is between March and May while the marked dry period lies between November and February.

Sampling technique

This study relied on three stage random sampling techniques. In the first stage, two Woredas were selected randomly from each target zone during dry and wet seasons to carried out survey type research. In the second stage, a total of four sample Kebeles were selected from these two Woredas based on the following parameters: 1) Major coffee producing PA from each woredas and 2) accessibility of the focal sites to transportation. In the third stage, thirty farm households per PA were selected to have a total of 240 farmer respondents on the basis of the following major parameters: 1) long experience and knowledge of growing coffee under key shade tree species, 2) the person interviewed falls into the category of either male or female household head or 3) willingness to participate in the investigation.

Methods of data collection

The exploratory survey was conducted in January and June 2013, during dry and wet season, respectively. Informal discussion was held with frontline extension personnel to identify villages to participate in surveys. Exploration for relevant information was continued through Participatory rural appraisal techniques, such as semi-structured questionnaire, transect walk, key informant interview (the key informants could be agricultural development agents or other identified elders from the community) and focused group discussion with an interdisciplinary team consisting of Forestry, Coffee Agronomy and Socio-economics Research Division.

Secondary data from Weredas Agricultural and Rural Development Offices were gathered to make a thorough comparison on shade tree trend analysis and socio-economic data. The collected information included 1) demographic and basic farm data, 2) shade trees and overall uses, 3) related to coffee agronomic practices and production systems and 4) shade tree management, through semi-structured interview schedules, key informants, and Focus Group Discussion to satisfy pre-determined objectives.

Data analysis

Finally, most of the collected data were analyzed accordingly using SPSS Version 16, computer program and the presentation was ended with tables, and figures. Descriptive statistics was the major statistical tool to analyze the collected data.

III. RESULTS

Demographic and Educational Characteristics of the Respondents

Age of the household head

Two hundred fourteen respondents were considered in this study, of which the majority (39.2 %) of the respondents' age lies between 35-50 years. The results further indicated smallest proportions of the respondents (3.3% of coffee producers) were within a range of 10-25 years of age. Concerning to sex, 98.8 % of the respondents' were male and the remaining 1.2% was females.

Education

With an adult literacy rate of 87.9%, the study identified a good level of education. This result is more than twice that of the national average (35.5% literacy rate) and it has important implications for augmenting the volume of production and sales of coffee in the study areas (Table 1).

Family size

Survey results showed that an increase in family size was directly proportional to allotted productive labor sources for coffee production (Table 1). Similarly, (Wolday 1994) reported that lower dependency ratios and larger family sizes positively affected the supply of avocados promoting better participation in markets documented that different labor sources are employed in horticulture in Eastern Ethiopia and family laborers account for the majority of labor allotments.

Table1. Demographic and Educational Characteristics of the Respondents

No	Items	Total	
		Frequency (f)	Percentage (%)
1	**Age of respondents**		
	10-25 years	8	3.3
	25-35 years	57	23.8
	35-50 years	94	39.2
	>50 years	81	33.8
2	Sex of respondents		
	Male	237	98.8
	Female	3	1.2

3	Level of education		
	Ilitiret	29	12.1
	Elementary(1-8)	136	56.7
	Secondary(9-12)	44	18.3
	Diploma(10+3)	8	3.3
4	Household member(Family size)		
	1-5 members	85	35.42
	6-10 members	145	60.42
	11-15 members	10	4.16

Access to important information on coffee growing and management 53.8% of the respondents were obtained from their elderly farmers, 45.1% of the respondents were obtained from agricultural and rural development offices (DAs), 9.1% of the respondents were obtained from their neighbors and the remaining 0.8% of respondents were obtaind from research center.

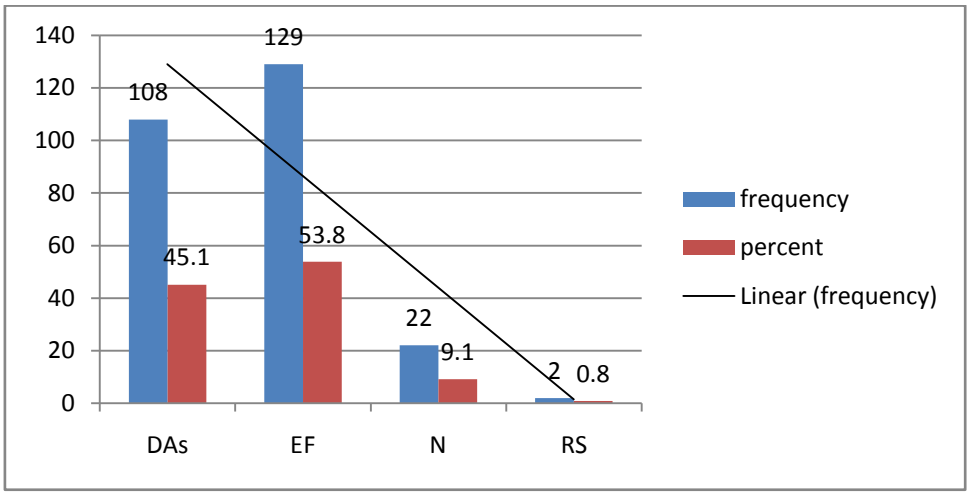

Figure 1 Access to important information

Figure1. Access to important information for coffee growing and manage mental practices, Southern Ethiopia. Abbreviations: DA=development agents, EF= elderly farmers, N = neighbors and RC= research center.

Farming experience: Farming experience of more than 10 years were reported by 83.4% of respondents, which likely increased the probability of HHH to be better able to participate in production and marketing of coffee in the study areas (Table 2).

Access to and use of land

From the total respondents 87.5% were have less than 2 ha the remaining 12.5% were have more than 2ha and its average land holdings in the study area was 1.25 ha, which is more than the national average (that is, 0.8 ha) (CSA, 2008). These large land holdings are primarily for coffee production which provides an opportunity for coffee production which supports crop diversification in South Ethiopia. Over 85.8% of respondents were coffee to be first in area coverage and all of the farmers in the area grow coffee (Table 2).

Regarding to coffee verities based on canopy nature, 40.4%, 30% and 26.7% of the respondents were cultivated open type, intermediate type and compact type of coffee varieties, respectively and the remaining 2.1% of respondents were not able to identify their coffee (Table 2).

Concerning to age of coffee trees, 38.3%, 25.8%, 22.9% and 12.1% of the respondents were mentioned between 11-20, between 1-10, between 20-30 and greater than 31 years, respectively (Table 2).

Table 2. General information related to coffee and basic farm data

No	Items	Total	
		Frequency (f)	Percentage (%)
1	**Farming Experience (growing coffee)**		
	for a decade	39	16.2
	for two to four decades	190	79.2
	for half century	10	4.2
	None respondent	1	0.4
2	**Total farm area owned and rented**		
	Less than a hectare	101	42.1
	1-2 hectare	109	45.4
	2-4 hectare	27	11.2
	more than 4 hectare	3	1.2
3	**Share of land under coffee**		
	<50%	34	14.1
	50-75%	146	60.8
	75-100%	60	25.0
4	**Coffee Varieties based on canopy nature**		
	Open	97	40.4
	Intermidiate	74	30.8
	Closed	64	26.7
	They don't no	5	2.1
5	**Year of planted (age) of coffee**		
	1-10	62	25.8
	11-20	92	38.3
	20-30	55	22.9
	>31	29	12.1

The main income sources for the household heads included coffee (85.8 %); all farmers grow coffee as the major cash source in the area. This result is in conformity with Ghirotti (1995) who has reported 98% of the farmers in the southwestern part of the country ranked coffee to be the major cash source.

Coffee is the major product of the farm household supplied to the market. Except the insignificant proportion of coffee consumed at home all of the production is supplied in the form of red cherry (for wet processing) and dry coffee.

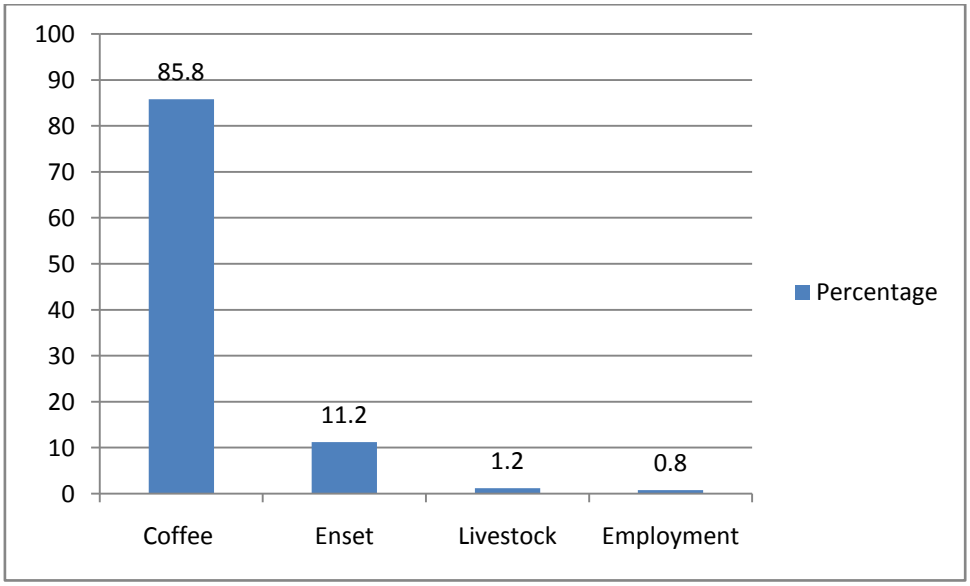

Figure 2: Major source of income for the house hold

Shade trees and farmers' perspectives

Most farmers in the study sites expressed their rich experience in replacing cut or dead shade trees by the original type species. The majority respondents (51.7%) mentioned that the shade trees were older than 10 years, regarding their seed source 80.4% of interviewees had mentioned that own resource, only 2.1% of respondents had obtained from nearby market. when it comes to best compatible coffee shade trees, 30.8%, 27.5%, 24.2%, 14.2% and 3.3% of the respondents were said Millettia ferruginea, Cordia Africana, Erythrina abyssinica, Ficus sur and Gravilia robusta compatible with coffee, respectively. Means of shade tree selection criteria 80.6%, 73.9%, 56%, 38.1%, 18.3% and 4.1% of the respondents were selected based on fast growth rate, less competitiveness, good light interception, adaptive reasons, and need of extra management and other, respectively.

Table 3 Shade trees and farmers' perspectives

No	Items	Total	
		Frequency (f)	Percentage (%)
1	**Year of planted (age) of shade trees**		
	Leas than 10	99	41.2
	Between 11 to 20	77	32.1
	Between 20 to 30	41	17.1
	Greater than 30	6	2.5
2	**Which shade trees species best compatible with coffee**		
	Ficus sure	34	14.2
	Cordia Africana	66	27.5
	Millettia ferruginea	74	30.8
	Erythrina abyssinica	58	24.2
	Gravilia robusta	8	3.3
3	**Where did you get these shade tree species**		
	Agricultural office	19	7.9
	Own sources	193	80.4
	Neighboring farmer	23	9.5
	Nearby local market	5	2.1
4	**What is/are your specific reason/s behind selections of shade tree species?**		
	Fast growth rate	91	38.1
	Adaptive reasons	134	56
	Less competitiveness	193	80.6
	Good light interception	177	73.9
	no need of extra management	44	18.3
	Others	10	4.1

Other benefits of shade tree species

More than 95% of respondents stated the benefits they obtained from coffee plants other than for drinking and main income source, firewood (90%), Timber value and construction (74.2%), honey /bee production (43.8%) and coffee plants get benefits from shade trees for nutrient acquisition and soil moisture improvement (6.2%) which was mainly linked to leaves of shade trees apart from shade provision to coffee plants (Table 4). More than 97% of the respondents cited that there is no problem related to shade trees. 2.9% of respondents from the total were said coffee plants get competition from shade trees for nutrient, water and sun light while we plant under shade trees, one respondent was said shade trees will create favorable micro-environment for the occurrence of same coffee disease.

Table 4 Other benefits of shade tree species

No	Items	Total	
		Frequency (f)	Percentage (%)
1	**Do you use them only for the shade purpose?**		
	Yes	10	4.2
	No	230	95.8
2	**Other benefits of shade trees**		
	Firewood	216	90
	Timber and construction value	151	74.2
	honey /bee production	105	43.8
	Other benefit(improvement of soil fertility and reduction of soil erosion)	15	6.2
3	**Problems related to the shade trees**		
	Yes	7	2.9
	No	233	97.1
4	**If yes, what was (where) problem(s)?**		
	Related to nutrient, water and sun light competition with coffee	6	85.7
	creation favorable micro-environment for the occurrence of same coffee disease	1	14.3

Preference of farmers on coffee shade trees

From the total respondents 50.8% were required shade trees for their field, 43.3% of respondents were not required shade trees for their coffee plantation and the remaining 5.8% of respondents were not responds. From the total respondents who were required shade trees, 47.54% *Cordia africana*, 28.69% *Millettia ferruginea*, 18.03% Ficus sure, 4.09% *Erythrina abissinica* and 1.65% Gravilia robusta prefered in consequence. The respondents chose the species based on the following criteria, improves soil fertility, increases productivity, Protects coffee from heavy sun, b/c of their compatability to coffee and construction purpose, 54.09% improve soil fertility, 17.21% increase productivity, 5.74% protecte coffee tree from heavy sun, 13.11% b/c of compatability and 9.84% construction purpose, in view of that the respondents were chosen the species.

Reason of the respondents who were not required shade trees, 82.69% were said we have eough shade trees and the remaining 17.31% of respondents were said we don't have free space to plant additional shade trees.

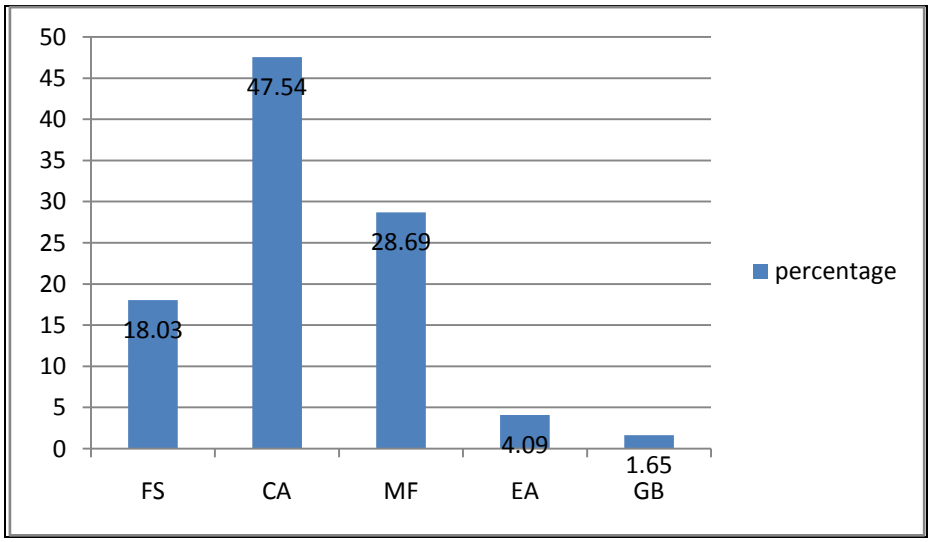

Figure3. Preference of farmers on coffee shade trees

Figure3. Preference of farmers on coffee shade trees, Southern Ethiopia, Abbreviations: FS=Ficus sur, CA= Cordia africana, MF = *Millettia ferruginea*, EA= *Erythrina abissinica* and GB= gravilia robusta.

Table 5 Preference of farmers on coffee shade trees

No	Items	Total	
		Frequency (f)	Percentage (%)
1	**Do you want shade tree seedlings for your coffee plantation?**		
	Yes	122	50.8
	No	104	43.3
	Indifferent	14	5.8
2	**If yes , in question no. 19 above, what type of shade tree species do you want?**		
	Ficus sure	22	18.03
	Cordia Africana	58	47.54
	Millettia ferruginea	35	28.69
	Erythrina abyssinica	5	4.09
	Gravilia Robusta	2	1.65
3	**Why do you want?**		
	Improves soil fertility	66	54.09
	Increases productivity	21	17.21
	Protects coffee from heavy sun	7	5.74
	b/c of there compatability to coffee	16	13.11
	for constraction	12	9.84
4	**What if no**		
	I have enough shade tree	86	82.69
	I don't have free spaces	18	17.31

Growth and management practice of coffee

Concerning to planting patter, from the total respondents 67.5% were planted in rows, 29.6% of respondents in dispersed manner and the remaining 1.7% of respondents was kept its standared. Relating to growth character, about 70.4 % of respondents had vigorous and good coffee plantation, 16.2% of respondents were have dwarf and the remaining 12.5% of respondents had poor performance coffee trees. In relation to cultural practice, from the total respondents 30.6% weeding, 22.9% compost application, 15.4% pruning and training, 7.7% intercropping and 23.4 % all management were done accordingly.

Responses regarding to physiological disorder, about 76.7% of respondents were mentioned there is problem of physiological disorder but the remaing 23.3% of respondents were said we did not face such a problem. From the total respondents who were thought about physiological disorder, 71.19% die-back, 11.41% drought symptom and 17.14% crinkled leaf were mentioned.

Responses regarding to major coffee diseases, from the total interviewees 73.7% were cited there is coffee disease, of which 55.93% CBD, 19.21% CWD and the rest 24.86% both of the two were observed.

Table 6 Growth and management practice of coffee

No	Item	Total	
		Frequency(f)	Percentage (%)
1	**Planting pattern of coffee stand(s)**		
	In rows	162	67.5
	In dispersed manner(as farmers like)	71	29.6
	Standard is kept	4	1.7

2	**Growth character or performance of coffee**		
	vigorous and good	169	70.4
	dwarf	39	16.2
	poor performance	30	12.5
3	**Type of coffee yield management activities**		
	pruning	37	15.4
	weed management/control	73	30.6
	compost application	55	22.9
	Intercropping	18	7.7
	all	57	23.4
4	**Is their physiological disorders**		
	Yes	184	76.7
	No	56	23.3
5	**Incidence of coffee physiological disorders**		
	Dieback	131	71.19
	Drought symptoms	21	11.41
	crinkled leaf	32	17.4
6	**Occurrence(s)of disease and insect pests with related to coffee**		
	Yes	177	73.7
	No	63	26.2
7	**If yes , what kind of disease and insec typest(s)**		
	CBD	99	55.93
	CWD	34	19.21
	CBD and CWD	44	24.86

IV. 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 favorable 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 of accumulated water (Beer, 1987; Beer et al., 1998).

The species diversity of common coffee shade trees (n=5) repeatedly mentioned by the interviewed farmers seemed very few as compared to the previous studies conducted in socioeconomic benefits of shade trees in southwestern Ethiopia (***Muleta et al***, 2011). In this investigation, farmers gave special emphasis to those shade trees which they mainly retained on their fields/farmlands for their favorable characteristics and other uses.

Most interviewed farmers cited *M. ferruginea*, *C. Africana*, *Erythrina abyssinica*, *Ficus sure*, *A. gummifera*, *A. abyssinica*, and gravilia robusta in that order as the best coffee shade tree species to have in their plots. The first one is 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;

The majority of the interviewed farmers signed out other desirable benefits derived from shaded systems. Some of the mentioned advantages such as firewood, timber value, construction and honey /bee production. Apart from shade provision to coffee bushes, some 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 under storey crops like cacao and coffee.

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 rate, less competitiveness, good light interception, adaptive reasons, deciduousness, and possession of thin and small leaves which all are generalized as suitability for coffee plants growth.

In general, since the shade trees (*M. ferruginea*, *Cordia africana* and *E. abyssinica*) 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 study stated that there were great potential shade trees in the study area as well as they preferred deciduous shade trees compared to evergreen ones. Additionally, Most of the respondents were cited that there is no problem related to shade trees. 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 uncertainty on evergreen trees for proper light penetration.

V. CONCLUSION AND RECOMMENDATION

Farmers have an excellent knowledge of the potential and constraints 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, training on uses of different coffee shade trees, their manage mental practices, legume plants and their association with beneficial soil microorganisms, involvement of microorganisms in organic matter transformation, and overall other interactions of coffee with shade trees should be provide to farmers to enrich their local knowledge and build ample self assurance about their critical observation and responses. In general, the shade trees *Millettia ferruginea*, *Cordia africana* and Erythrina *abyssinica* are recommended for the study area.

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