ISSN 2664-4169 (Print) & ISSN 2664-7923 (Online)
South Asian Research Journal of Biology and Applied Biosciences
Abbreviated Key Title: South Asian Res J Bio Appl Biosci

| Volume-4 | Issue-2 | May-Jun -2022 | **DOI: 10.36346/sarjbab.2022.v04i02.002**

Original Research Article

The Role of Shade Trees in Coffee Production Systems: The Case of Yayo District, Ilubabora Zone, Oromiya Region, Southwest Ethiopia

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Article History
Received: 06.04.2022; Accepted: 08.05.2022; Published: 18.05.2022

Abstract: Coffee is one of the world's most important crops given the highest number of people living directly or indirectly from it. Farmers have an excellent local knowledge about different tree species which are either retained or planted on their farms. The main purpose of this study was to investigate coffee growers' local knowledge on the roles of shade trees in coffee production systems at Yayo District in Ilubabor Zone Southwest part of Ethiopia. A total of 120 (20 key informants and 100 households) participated in interview. Data were collected by using semi structured interview and field observation. The data were analyzed by preference ranking, direct matrix and using descriptive statistics. A total of 20 most commonly used coffee shade tree species belonging to 16 genera and 7 families were identified in the study area. Fabaceae was the most species rich plant family followed by Euphorbiaceae and Moraceae .The coffee farmers in the study area are mentioned benefits of the shade trees such as for improvement of soil fertility and moisture, to protect from unsuitable environmental stress, for longer life span of coffee plants, reducing erosion, increase coffee yields and quality, and reduce weed and grasses. Among shade tree species best compatible with coffee plant such as Albizia gummifera, Acacia abyssinica, Albizia schimmperia, Millitia ferruginea, Albizia grandibracteata ,Cordian africana and least were Corton macrostachyus were highly favored in that order. However, farmers considered as preferred coffee shade trees species by characteristics were mainly based on tree height, fast decomposition rate, small deciduous compound leaves, and umbrella crown shape and root depth. Coffee farmers of the study area managed their owned shade tree species through pruning, mulching and composting, thinning, weeding and hoeing and debarking and intercropping operations. To agreement endorsement of the extension of coffee shade agroforestry knowledge, the rural households must participate in pieces of training to improve their productivity and maximize the benefits of coffee shade in coffee production system.

Keywords: Coffee arbica, Yayo district, coffee farmers, coffee shade tree species.

1. INTRODUCTION

Coffee is one of the world's most important crops given the highest number of people living directly or indirectly from it. Coffee arabica is the most important source of foreign currency for many developing countries. Ethiopia is the primary center of origin and genetic diversity of Arabica coffee plant. Coffee is important to the economy of Ethiopia; around 60% of foreign income comes from coffee, with an estimated 15 million of the population relying on some aspect of coffee production for their livelihood. Coffee is shade-tolerant plant and is mainly grown under shade trees in complex agroforestry systems. Seventy percent 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 Coffee arbica (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 small-scale growers (95%) under rain-fed and low input production systems making the shaded Ethiopian coffee production naturally 'organic' (Petit, 2007). Shading buffers the extreme temperature variations and provides a microclimate which attenuates extreme temperatures of air and soil and preserves surface soil humidity. Photosynthetic rate of coffee plants that are grown exposed to direct sun light is limited by stomata closure, high leaf temperature and low internal carbon dioxide concentration. Similarly, (Sethar *et al.*, 2002) indicated that the physiological processes of plants are temperature dependent, and under high temperature crops have great difficulty in

maintaining photosynthetic activities and growth. The production of heavier and larger coffee beans is mainly caused by the effect of temperature and the duration of the ripening period, which is also induced by shade. Muschler (2001), who found comparable results, indicated that coffee bean size significantly and consistently increases even with increasing shade levels. Similarly, the shade effect on liquor taste was also the result of delayed fruit maturation and growing. Coffee can be cultivated within the range of 800 m to 2500 m above sea level, mean annual rainfall of 900–2000 mm and temperature range of 15-32^{0}C. Indigenous people have local knowledge on plant resource and their uses. Farmers in southwestern part of Ethiopia, have life long experience in growing coffee under various types of shade trees (FAO, 1968). Nowadays, shaded coffee production system has received an enormous amount of attention from conservation organizations since it promotes biodiversity conservation while enhancing income generation from the sale of both timber and non-timber forest products as well as involving in carbon sequestration. Yayo district is one of our research areas which are a very high amount of coffee production people lives and their primary source of incoming is depended on coffee production. Like many other parts of the country, there is no such the benefit of coffee shade research and documentation carried out in Yayo District, Ilubabur Zone, Oromiya Regional states. But research study on the subject of the role of coffee shade tree species in this area is scanty. Therefore this study has been initiated to identify the most important coffee shade tree species for coffee production from farmers' point of view and, to identify coffee farmer's local knowledge on the management of coffee shade tree species and to document farmers' traditional knowledge on the benefits of various shade trees for coffee plants in the area.

2. MATERIALS AND METHODS

2.1. Description of the study area

The study was conducted at Yayo districts in Ilu Abba Bor Zone of Oromia National Regional State that is found at about 564 Km southwest of Addis Ababa, the capital of Ethiopia respectively and 36km from zonal capital city of Mettu Town. Yayo district is one of the few areas in the country that is endowed with a variety of plant species including endemic ones. The forest covers about 90890.7 hectors constituting 58.8 % of the total area of the districts .Yayo forest represents the largest forest10,000ha undisturbed forest fragment kept for the conservation of wild *Coffee arbica* population early identified as potential coffee gene reserves).

The study area is located between latitude 8°2l'-8°26' North, and longitude 35°45' -36°03' East and alititud1139-2570m.a.s.l. The total area of the district has 162,901 hectors (1,629.0km^2). The annual rain fall pattern of the district varies annually from1750-1960.7mm showing variation s from year to year. It is said to be unimodal types of rain fall increase from May to October and decline in Novembers. The mean annual temperature 20°C-30°C and humidity 60-70.The soil types of Yayo Woreda are clay sandy. The district has three agro climatic zone which is includes highland (badda) temperate (Badda-daree) and lowland (Gammoojji).

Yayo district is bordered by Dorani and Alge Sachi districts in the North, Chora district in the East, Hurumu district in the West and Sigmo-seta district (Jimma zone) in the South. It includes eighteen (18) administrative Kebeles including an addition Kebele of Yayo town. Coffee is an important cash crop in the area with over 50 km^2 plantation .The main source of income in the community of the district is coffee production and the annual coffee production of community per year 15000 tone. The total size of investigation coffee system rang 17020hectors among this 346 hectare coffee forest 5470ha home garden coffee and 7974hactor is semi forest coffee respectively (Yayo Agricultural Office, 2021).

The total population of Yayo district is 61,439, comprising 31,936 males and 29,503 females while the total numbers of households in the district is 11, 9640 comprising 10,197 males and 1,767 females. The Oromo are the major ethnic group (85%) followed by followed by the Amhara (8%), Tigrayan (4%) and others (3%).

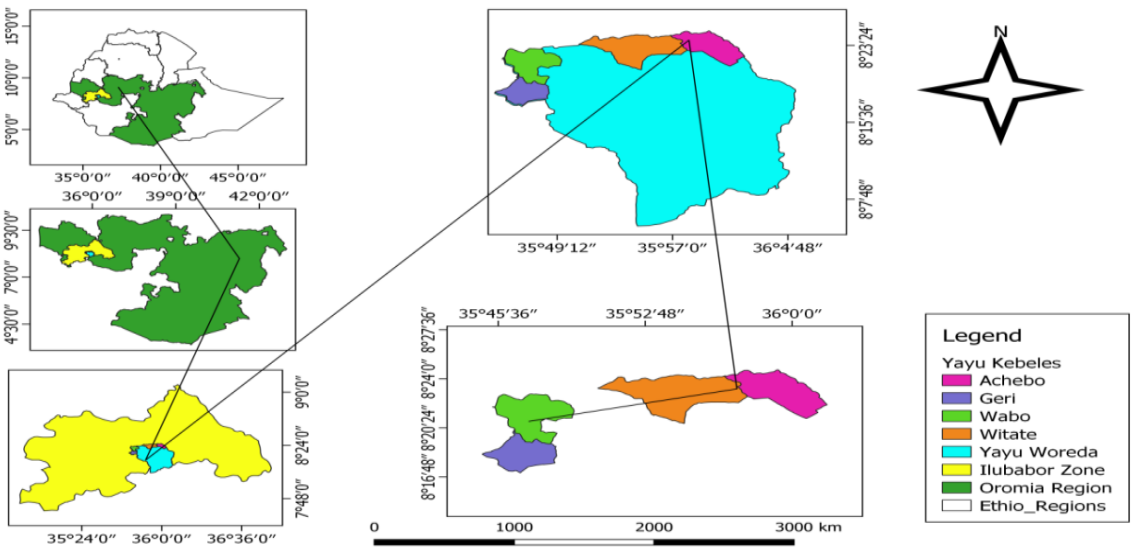

Figure 1: Map of study area

2.2. Sampling techniques and selection of respondents

2.2.1. Selection of the Study Sites

Primarily, the study district was selected purposively based on the availability of coffee shade tree species; and based on probability of highly coffee production. There are 17 kebeles in the study district known for major shaded coffee production and four kebeles namely Geri, Waabo, Wutate and Aciboo were purposively selected based on the on the areas' past richness in various coffee product, it is one of coffee biosphere reserves , their intensive use of shade tree for coffee plantation in their farmland, exploitation of shade trees products the high amount of coffee will produces and absence of conservation practice of shade tree and also the fact that shade trees degradation in the Woreda is the major issue in the communities from 13 Woreda of Illu Aba bora zone for the study area. The information sources to the selected five kebeles were chosen from amongst the elderly, as well as from the local authorities of the Woreda and yayo woreda coffee development agricultural and natural resource office.

2.2.2. Selection of sample households and key informants

In this study, a household is defined as a basic unit of production and consumption, made up of the persons who have common fields and live under one central decision-maker. There are several approaches used to determine the sample size of households. These include using a census for small populations, imitating a sample size of similar studies, using published tables and applying formulas to calculate a sample size (Israel, 2012). This study applied the simplified formula developed by Yamane (1967) and reviewed by Israel (2012).

A total of 120 informants (74 male and 46 female) 20 individuals from each of the study four *kebeles* from age of above 20 years was selected by purposive and snowball sampling techniques from the local communities, respectively. The sample size was determined by using the formula Yemane (1967).

$n= \frac{N}{1+N(e)^2}$ Where n is sample size of the study area,

n= Where, N= population size n= sample size e= acceptable level of error (0.05), Therefore, the sample size was determined by this equation.

From these study site, 20 key informants was selected purposely among those *kebeles* who called as "The father of coffee farmers" are on the basis of long experience coffee farming, and knowledge of growing coffee under key shade tree species. Key informants, was identified by with the assistance of local *kebele* authorities.

2.3. METHOD OF DATA COLLECTION

The data was collected between Septembers to October 2021 two field trips. The data can be collected based on prepared questionnaires, semi-structured interviewees, observation, focus group discussion, and guided field walks with key informants were employed to obtain indigenous knowledge of the local community of study area. All of the interviews were held in Afana Oromo language of the local people.

2.4. METHODS OF DATA ANALYSIS

The collected data from the questionnaires of household interview responses were coded and entered into Microsoft Office Excel sheet. Data were grouped and summed by response category on the data sheet. After organizing the data on Microsoft Office Excel, the analysis was performed using Statistical Package for Social Science version.20 for windows (SPSS) software. The data can be analyses tools was analyzes descriptive statistics was employed to percentage and an ethnobotanical methods of data analysis like preference ranking to assess the degree of selected coffee shade trees following Martin (1995). Generally, direct matrix ranking to compare multipurpose coffee shade trees following Cotton (1996) was used to analyze and summarize the data on types of coffee shade trees, the benefit to coffee plant, their additional values and also the most threatened coffee shade trees was analyzed through descriptive statistics.

3. RESULTS AND DISCUSSION

3.1. The respondents' demographic data

Age and sex of household

There are one hundred twenty respondents considered in this study area, 61.7% males and 38.3% are female. The ages of household heads the ranged from 20-75 above years. But the major age groups were the (65.8 %) of the respondents' age lies between 35-50 years.

Education status

The respondents educational level were; illiterate 50.0% those with adult education, 16.7% attend both primary (grade 1-8) & secondary school (grade 9-12) 9.2% have diploma respectively. This shows that there is a negative relationship with literate. In comparison of educational status, non-educated informants handled much knowledge of coffee shade trees whereas educated informants had low knowledge due to which is an indicative of impact of modern education.

The total annual farmers' net income ranged from 21,000-30,000 Ethiopian Birr was 53.3%. Most of the interviewed farmers' holdings in the coffee farms range from 0.5 to 15 hectares. The main income sources for the household heads included 75% coffee production, 20% coffee and other crops and 5% non-coffee crops cultivated were mainly cereal crops and honey production.

Therefore, almost all farmers grow coffee as the major income source in the study area. The majority of farmers which were 45 (37.5 %) of them owned rang 0.5-2ha, 30(25.0%) between rang 2-3, less than 0.5 hectares of coffee farms 20 (16.7 %) of farmers owned 2-3 hectares and 25(20.5%) of them owned greater than3hectares of coffee farms. The majority of household farmers which were 65 (54.16%) have coffee trees ages rang which are above 10 -15years**.**

Table-1: Respondents' demographic and basic farmer's data

Variable	Frequency	Percentage
Sex		
Male	74	61.7
Female	46	38.3
Age		
20	1	0.8
21-35	20	16.7
36-55	79	65.8
56-75	18	15.0
>75	2	1.7
Educational background		
Illiterate	60	50.0
Primary school	20	16.7
Secondary school	20	16.7
Diploma	11	9.2
>diploma	9	7.5
Annual net income (Birr)		
<20,000	40	33.3
21,000-30,000	64	53.3
31,000-40,000	10	8.3
>41,000	6	5.0
Main income source of house hold		
Coffee production	90	75%

Non coffee production	6	5%
Both coffee and other crops	24d	20%
Total area covered by coffee (Ha)		
<0.5	20	16.7
0.5-2	45	37.5
2-3	30	25.0
>3	25	20.8
Coffee farmer tree ages(year)		
<10	10	8.3
10-15	65	54.16
16-20	25	20.8
>21	20	16.7

3.2. Source of indigenous knowledge

Coffee growers in the study area obtain information about coffee shade trees and other management techniques from different sources. According to respondents, majority from indigenous coffee farmers (57.5%), from agricultural and rural development offices, (25.8%), from NGOs (10%) and from research center (6.66%). Because elder coffee growers are more knowledgeable through long years of experience; they are more knowledgeable on coffee shade trees characteristics. These results agree with other studies such as Ashenafi *et al*., (2014). (Table3).

Table-2: Source of obtained knowledge on coffee growing and management

Source of obtained knowledge	frequency	percentage
Indigenous Coffee growers	69	57.5
Agricultural expert and rural dev't office	31	25.8
NGOs	12	10
Research center	8	6.66

Source: From Yayo Woreda Survey Result (2014/2021).

3.3. Coffee Shade Trees in Yayo Worda

A total of 20 tree species belonging to 16 genera and 7 families were collected and identified in the study area. In regards of family distribution Fabaceae stood first with comprising 11 (55%) species and followed by Euphorbiaceae and Moraceae each contains 3(15%) and 2(10%) species. The remaining families contain one species per family. The majority of coffee shade trees of the study area are Fabaceae, Euphorbiaceae and Moraceae. This result is the line with the finding in Ethiopia by Beer *et al*., 1998; Muleta *et al.*, 2011; Molla, 2015; Abdo, 2016; Kitessa, 2016, because of the area availability considerable diversity of plant species in farming sites, are believed to have capacity of nitrogen fixing leguminous species with morphological characteristics were considered as preferred coffee shade tree family by farmers and Contributing to the improved soil fertility reported by farmer (Appendex1).

3.4. Coffee Shade Tree Management practices

A number of coffee shade tree management practices are known among the indigenous communities of Yayo district. The study revealed that some 37.5% of the respondents use pruning to manage their coffee shade trees. Others use mulching and compost application (26.6%), thinning (26.6%), weeding and hoeing (10%) while very few of the respondents use debarking (7.5%) and intercropping (5.83%).

Coffee growers at the study site have good experience on management of shade tree species through different management operations. However, the scale of shade tree species managements of coffee growers of the study district are varies. About 37.5%) and 26.6% of the respondents employed pruning and mulching and compositing operation for their owned different shade tree species, respectively (Table 3) .Pruning of shade trees is the most widely practiced management technique in the study area to avoid dense canopy cover that cast heavy shade on coffee plants. Pruning is also done to reduce branches of shade tree for better growth when coffee growers need the shade trees for timber production. The finding of this study is in line with previous studies such as Motuma (2006) Aschalew and Zebene (2018) and Tolera and kidist (2021).They indicated that coffee growers in different parts of Ethiopia practiced pruning of indigenous woody species and coffee shade trees to reduce the effect of shade on understory crops, to get other additional benefits and to improve coffee production.

Farmers manage coffee shade tree canopy to optimize coffee production while maximizing the use of the different tree species. Shade management options are available to improve the attractiveness of coffee systems, while simultaneously maintaining coffee output at regular and productive levels. Dead or dry weeds and the residues of pruning can be used as mulch. Mulching will reduce the number of weeds, as well as water losses by evaporation, and added to soil by microbial decomposition.

The respondents in the study district also use thinning operation for densely growing naturally regenerated shade tree species. It is well recognized that shade trees in the natural forest are characterized by high density, closed canopy cover and cast heavy shade on coffee plants. To reduce heavy shade cover on coffee plants, to minimize competition between shade tree and coffee plants and to create good conducive environment for coffee plants, farmers employed thinning operation (Table 3). Similarly, Mesele (2007) indicated that farmers in Gedio Zone, Southern Ethiopia, practiced thinning operation, when crowns of adjacent tree species started to close and create heavy shade on under story crops. Moreover, Regina *et al.* (2012) on their study in southern Bahia, Brazil, indicated that cacao growers deliberately reduced densely grown over story cacao trees through thinning management practice, to minimize negative effect of shade tree species on understory cacao trees. This finding is similar to that of Aerts *et al.*, (2011), Schmitt *et al.*, (2010) and Tolera and kidist, (2021).

Farmers in the study area also managed coffee plant by intercropping different crops like spice such as *Afromomum korrorimum*, *Piper capense* and *Zingiber officinale* and cereals and legumes with coffees. Cereal crops like *Zea mays*, *Sorghum bicolor* and legumes such as *Vicia faba* and *Phaseolus spp* are also grown in coffee farms together with coffees. Intercropping with *Musa paradisica* is also practiced either because it acts as a shade 'tree' itself or done under taller shade trees around homestead areas. *Musa paradisica* is used as an additional income source and food supplement and also to reduce soil erosion.

When farmers manage one of the crops, the other crops are also benefited. Inter-planting with some other crops helps reduce soil temperature, smothers weed growth and supplies the soil with organic matter as crop residues are turned back into the soil Diriba *et al*, (2011); Aboma, (2016). This idea was also supported by key informants and during filed observation in coffee farms.

Table-3: Shade tree management practices experienced by adopters in Yayo Woreda

Management practices	Frequency	Percentage
Pruning or pollarding	45	37.5
Mulching and composting	32	26.6
Thinning	22	18.3
Weeding and hoeing	12	10
Debarking	9	7.5
Intercropping	7	5.83

Source: From Yayo Woreda Survey Result (2014/2021).

3.5. Benefits of the Coffee Shade Trees in the study area

The benefits of coffee shade trees are well recognized by coffee growers in the study area. The majority of respondent (99.1%) cited that shade trees are used to improve soil fertility and moisture content. Some 97.1% indicated coffee shade trees can regulate light penetration, 96.6% indicated that shade trees increase the lifespan of coffee trees, 94.1% agreed that shade trees reduce soil erosion, 93.2% indicated that shade trees increase coffee yield and quality and 91.5% indicated that coffee shade trees reduce weed and grasses (Table 4).

According to both key informants and respondent households, shade grown coffee plants have better coffee yields and quality may be due to leaf litter decomposition that improved soil fertility under coffee plants. Moreover, shade grown coffee plants are protected from adverse environmental stress. As a result, coffee plants under optimum shade are healthy, flower on time and produce better coffee yields. Soto Pinto *et al* (2007), Diriba *et al.* (2011), Robert (2011), Ashenafi *et al.* (2014) and Aschalew and Zebene ,(2018) also indicated that shade trees have a positive effect on coffee plants and contribute to better coffee yields than those grown under full sun. Adugna and Paul (2014) also showed that coffee beans developed under shaded condition were heavier, larger in size and had better liquor taste. However, greater coffee yields are obtained from sun grown coffee plants. Haggar *et al.* (2011) also indicated that shade trees compete with coffee for resources and in a very wet year, shade can promote the growth of moisture-loving fungi, which may reduce the yield of shade-grown coffee plants.

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 understory crops like cacao and coffee.

Respondents in the study area also indicated that shade trees are vital to protect the new planted coffee seedlings from undesirable environmental stress that would reduce their survival. Moreover, shade trees protect coffee plants from adverse climate conditions during their flowering and fruiting stage. This idea is in agreement with previous studies such as Albertin and Nair (2004), Claudia, (2010), Santos *et al.* (2012) and Adugna and Paul (2014). They indicated that shade trees improve the climate for coffee plants by buffering temperature extremes in the air and soil and by reducing wind velocity in coffee plantations.

The key informants and the general household respondents all agreed that shade grown coffee plants have longer life span than those grown under full sun (Aschalew and Zebene, 2018). Shade trees are also suppressed weeds and grasses. Other coffee management practices such as slashing of weeds and emergent trees from coffee farms increases coffee yields (Feyera Senbeta and Danisch, (2006).

Table-4: Benefits of Coffee Shade Trees for Coffee Production

No	Benefits of shade tree for coffee trees	Frequency	Percent
1	Improvements soil moistures and fertility	119	99.1
2	Regulate light penetration for coffee plants (adverse environmental stress	117	97.0
3	It increase coffee trees longevity(long life Spain)	116	96.6
4	Reduce soil erosion	110	94.0
5	It increases coffee yields and quality	100	93.2
6	It reduces weeds and grasses	96	91.5

Source: From Yayo Woreda Survey Result (2014/2021).

3.6. Other Benefits of Coffee Shade Trees

Incorporating shade trees in coffee farm has numerous socioeconomic and environmental benefits in the Yayo district. Accordingly, principal socioeconomic benefits of coffee shade trees, include honey production, source of biomass energy, source of medicine, source of feed for livestock and human food and source of timber /construction wood apart from shade provision to coffee plant (Table 5).

In addition, shade trees incorporate 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); Sota pinto *et al.,* 2007); Ashenafi *et al.* (2014); Molla, 2015); Tolera and Kidist, 2021).Income generation from the sale of timber and non-timber products is also well documented in growing coffee with shade trees and other crops Molla, 2015).In addition to their economic role, respondents in the study area recognized the ecological benefits of coffee shade trees such as erosion control and soil fertility improvement, soil moisture conservation, biodiversity conservation microclimate regulation, minimizing environmental contamination and use as weed controlling mechanism.

Previous studies have also demonstrated the multiple uses of coffee shade trees and their role in erosion control and improving soil fertility, biodiversity conservation, pest and disease management, microclimate regulation and prevention of coffee plants from damage by frost or other extreme conditions and weed control (Perfecto *et al.,*2007; *Haarer1963;* Wiersum,*1984;* Beer *et al*., 1998; Bhagwat *et al.,*2008), Diriba *et al*., 2008; Wrigley 1988; Molla, 2015), (Willy,1975, kuit *et al.,2004;* (Goldberg and Kigel, 1986; and Abdo , 2017).

Table-5: The importance of shade trees mentioned by farmers in Yayo Woreda

Socioeconomic benefit of shade tree	No. of HHs	Frequency %
Honey been production	41	34.1
Source of energy/charcoal and firewood	23	19.1
Source of medicine purpose	15	12.5
Source of feed for animal and human	12	10
Timber production/construction material	10	8.33
Ecological benefits of shade tree		
Control erosion and Improve soil fertility	98	81.6
Serve as Soil moisture conservation	83	69.1
Serve as biodiversity conservation	76	63
Pest and disease management	62	51.6
Micro climate regulation and prevention	59	49.1
Minimize environmental pollution	51	42.5
Weed and grass controlling	45	37.5

Source: From Yayo Woreda Survey Result (2014/2021).

3.8. The Source of getting coffee shade trees

In addition to naturally grown shade tree species, planting of different shade tree species is widely practiced in the study district. Large majority of coffee farmer in the study area get shade tree seedlings from government agencies and NGO nursery sites (48.33%). The rest of the respondents (26.6%) obtain coffee shade tree seedlings from their own

nurseries (Table 6).

Moreover, both key informants and sampled households confirmed that some farmers collect naturally regenerating shade tree species from the nearby natural forest and transplant them on their coffee farms. Commonly, they collect the seedlings *of Cordia africana, Millettia ferruginea, Ficus vast, Croton macrostachyus and Albizia gummifera* from natural forest and transplant them in their coffee farms. But the study by Ashenafi *et al.,* (2016) and Aschalew, (2018) is against this fact. Coffee growers have profound knowledge about management practice of various shade tree species they owned. The trends of planting different coffee shade trees are commonly known in the study site and farmers have various source of planting material.

Table-6: The source of coffee shade tree planting material

Farmers' source of shade tree planting material	Number of respondents(HH) in the Study area	
	Frequency	Percentage
From government & NGO nursery site office	58	48.33
Own Self- nursery	32	26.66
From natural forest	20	16.66
From neighbor farmer	7	5.83
From nearby market	3	2.50

Source: From Yayo Woreda Survey Result (2014/2021

3.9. Preference of Farmers on Coffee Shade Trees

In the study district, 20 species are commonly used as shade trees in coffee farms. Among these, *Albizia gummifera 99.1%, Acacia abyssinica 93.3%, Albizia schimmperia 85%, Millettia ferruginea 84.1%, Albizia grandibracteata 83%, Cordia africana 77.5% and Corton macrostachyus* 74.1% are the most preferred in the area (figure 2).

Similarly, leguminous plants are known to be the most preferred shade trees by coffee growers across the globe (Beer, 1987; Grossman, 2003; Albertin and Nair, (2004). Tree parameters considered by farmers are their ability to increase soil organic matter (Beer *et al.,* 1998; Grossman, 2003), rapid decomposition rate, the ability to control soil temperature and soil moisture, erosion control, better growth and yield of crop under shade tree.This finding in line with previous studies (Beer, 1987; Beer *et al.,* 1998; Grossman, 2003; Albertin and Nair, 2004; Diriba .M *et al.,* 2011; Ashenafi *et al.* (2014); Aschalew and Zebene, 2018; Dereje *et al.,* 2016). Native leguminous tree species are often used to supply all or a portion of the nitrogen needed by coffee bushes (Soto Pinto *et al.,* 2000).

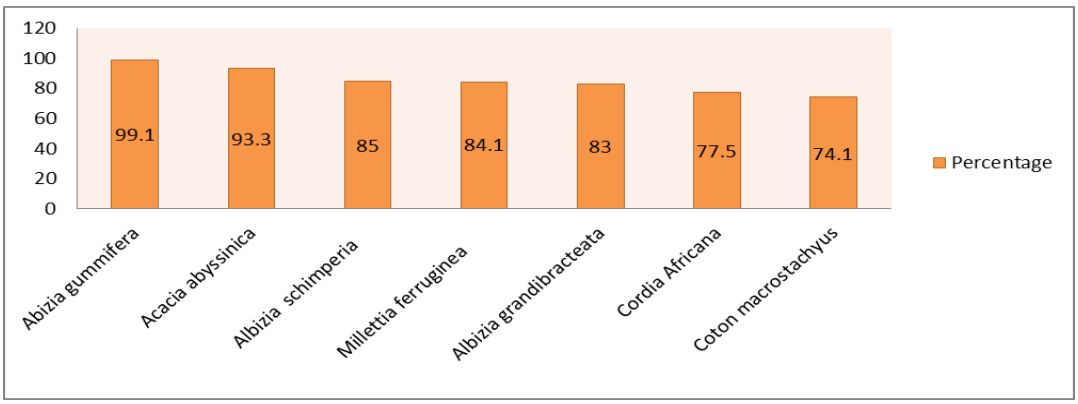

Figure: 2 Tree species most commonly mentioned by farmers as growing in study area

3.10. Selection Criteria of Coffee Shade tree in study area

The preference of coffee shade trees in the study area is based on a wide variety of tree characteristic such as height, crown width, leaf size, and deciduousness and litter decomposition rate (Albertin and Nair, 2004; Diriba *et al,.* 2011). Accordingly, coffee growers in Yayo district prefer deep rooted, taller trees, with wide spreading crown and deciduous small leaves that are rapidly decomposed, 85% as favorable shade trees.

However, respondents in the study area varied on the preferences of shade tree characteristics. In terms of height, majority (71.3%) of the respondents prefer longer tree species (Table 10). Longer shade trees are preferred because they provide adequate sun light to coffee plants and for hanging beehives. Tall trees are also important source of timber and construction wood. Albertin and Nair (2004) and Soto-Pinto et al. (2007) on their study at the northern Tzeltal zone of the state of Chiapas, Mexico and in Nicoya Peninsula, Costa Rica, respectively also indicated that coffee farmers prefer longer shade tree species on their coffee farms. However, their findings did not indicate the reason why coffee growing farmers prefer longer shade tree. On the other hand, about 16.2% of the respondents preferred shorter shade tree

species. Shorter shade trees are suitable for different management and little damage to coffee plants from different tending operation. Similar finding was also reported by Albertin and Nair (2004) and Samuel (2012). On their study, in Nicoya Peninsula, Costa Rica and in Ejisu-Juaben district, Ghana they indicated that farmers' preferences of shorter shade trees is because droplets from shorter shade trees cause risk of erosion than taller shade trees and management is easier for shorter shade tree. Some respondents (12.5%) in the study area preferred combination of both shorter and longer shade tree species (Table 7). This is because when longer and mature shade trees are harvested for various uses, the remaining shorter shade tree species provides shade for coffee plants.

With regard to crown size, large majority of farmers (70.8%) 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 because few shade trees with spreading crown provides adequate shade to coffee plants and is easier to manage as well as suitable for bee keeping (Table 7). Albertin and Nair (2004) also indicated that coffee growers in Peninsula of Nicoya, Costa Rica preferred shade trees with spreading crown since they provide better shade to coffee plants and for good management practice of those shade trees. On the other hand, about 21.2% of the respondents preferred shade tree species with narrow crown, since they need to have more diverse shade tree species on their small size of coffee farms. Evergreen shade tree species are preferred by only 16.6% of the respondents in the study area because they use them as a source of animal fodder during long dry season and crucial to protect coffee plants from extreme sun light throughout the year. In line with, Albertin and Nair (2004), Diriba *et al.* (2011) and Samuel, (2012) on their study indicated that farmers in Costa Rica, South Western Ethiopia, and in Ejisu-Juaben district, Ghana, respectively preferred evergreen shade trees over deciduous ones because coffees are obligate shade plant especially in the dry season. On the other hand, 74.1% of households preferred deciduous shade tree species mainly for nutrient cycling through litter fall. Beer (1987) and Ashenafi *et al.* (2014) also indicated that coffee farmers prefer deciduous shade tree species over the evergreen. About the remaining respondents (16.6%) preferred evergreen shade tree species (Table 7). This is because evergreen species provide shade when the deciduous species are shedding their litter and protect coffee plants from adverse environmental stress.

In terms of leaf size and shape, 54.1% of respondent in Yayo district preferred shade trees with smaller and thinner leaves to obtain moderate light penetration to coffee plants. Trees whose leaves are rapidly decomposing are also more preferred by coffee growers in the study area may be because decomposition increases soil fertility and contribute to rapid growth of coffee plants. Deep rooted trees are also preferred more than shallow rooted ones which could be associated to efficient nutrient absorption from depth of the soil where coffee roots cannot reach due to which there will be only minimum competition with coffees for nutrients. Through leaf litter decomposition, coffee trees obtain mineral nutrients from the upper soil layer (Kuit *et al*., (2004); Abdo, 2017). Moreover, deep rooted shade trees are more resistant to strong winds so could not fall and damage coffee plants. This is in line with the findings of Aboma (2016).

Table-7: Farmers' Preferences of Shade-Tree Characteristics in the Yayo District

Selection Criteria of coffee Shade tree	Farmers preference	Frequency of response number	%
Tree height	Tall shade tree	75	62.5
	Shorter shade tree	15	12.5
	Combination of both	30	25
Tree leaf size	Small leaf size	65	54.1
	Big leaf	30	25
	No effect	25	20.8
Tree root depth	Deeper	96	80
	Shallower	14	11.6
	Medium	10	8.33
Decomposition rate	Fast decomposer	90	75
	Slow decomposer	10	8.33
	Medium	20	16.66
Deciduousness'	Deciduous	89	74.1
	Every green	20	16.6
	Both deciduous and evergreen	11	9.16
Crown shape	Umbrella crown	85	70.8
	Narrow crown	20	16.66
	No effect	15	12.5

Source: From Yayo Woreda Survey Result (2014/2021).

Threatened coffee shade tree in study area

Ranking of 5 coffee shade trees based on the degree of threats was conducted using 10 key informants (Table 8). Result indicated that *Albizia schimperiana,* and *Cordia africana are* the most threatened shade tree species followed by *Pouteria adolfi-friedrici*, *Militia ferruginea* and *Albizia gummifera* in decreasing order.

Albizia schimperiana highly threatened coffee shade tree in Yayo district of southwest Ethiopia because of its slow growth rate, and slashing and removal of its seedling along with weeds. Human induced disturbance, feeding of its barks by Colobus guereza and attack of tree stems by ants and worms might have contributed to the reduction in stem density and species richness (Kumsa *et al.,* 2016) as well as. Farmers solved these problems by their indigenous shade tree management practices such as by growing its seedlings under *Corton macrostachyus* and by removing nets of ants from the stems.

Cordia africana is threatened species even at national level because of its excessive exploitation for its quality timber, wide use of this species for fuel and other local utilities. Similar threat factor was reported for *Cordia africana* by IBC (2012); Behailu, (2010) and Dirriba *et al.,* (2011)**.** *Pouteria adolfi-friedrici* is the third threatened shade tree in the study area because of mostly utilized multipurpose plant species by the local community, the less rate of replantation in the farmland, lack of intensive management in the study area, this idea is strengthens by the key informant and household of the study area Aboma (2016) indicated.

Table-8: Ranking of threatened shade tree

Name of plants species	Respondents(R1-R10)											
	R_1	R_2	R_3	R_4	R_5	R_6	R_7	R_8	R_9	R_{10}	Total	Rank
Cordia africana lam,	1	4	3	0	1	1	2	4	5	4	35	2nd
Millittia ferruginea	4	1	2	2	4	5	5	4	2	1	30	4th
Pouteria adolfi-friedrici	1	2	4	2	4	2	4	4	3	5	31	3rd
Albizia schimperiana	4	2	4	4	5	1	5	4	4	5	38	1st
Albizia gummifera	2	2	1	4	3	2	4	3	2	5	28	5th

Direct Matrix Ranking

Direct matrix ranking was performed to assess the relative importance of each of the coffee shade trees. The result of direct matrix ranking showed that *Albizia gummifera* stood first in being the most multipurpose Coffee shade tree followed by *Cordia Africana, Milltia ferrugenia, Corton macrostuchyus, Scheffelera abyssinica ,Vernonia amygdaline, Pouteria aldofi, Sasbanian sasbine, Alibizia schimperiana and Acacia abyssinica* (Table 9).

Majority of the interviewed farmers perceived other desirable benefits derived from shade trees. Some of the mentioned benefits of shade trees are fodder, firewood, timber, construction materials, erosion control, improved soil fertility, honey production, and medicinal value. All shade trees are grown in coffee plantation because of their additional economic benefits that they provide to the farmers. *Albizia gummifera* was typically superior in improving soil fertility, biodiversity conservation, minimizing erosion, increase coffee bean size and source of fuel fire contribution wood. *Cordia africana* was the second superior coffee shade tree because its edible fruit by both human and wild animals, source of wood for construction and timber, medicinal value, soil erosion control and fire wood. *Milltia ferrugenia* was considered third superior for its medicinal value, improve soil fertility, increase coffee bean size & yield, honey been production and construction materials (Table 9).

Table-9: Direct matrix ranking by eight key informants to compare the use values of each coffee shade trees (5 = the best, 4 = very good, 3 = good, 2 = less used, 1 = the least, 0 = not used).

Name Plant species	Use categories of coffee shade tree											
	Medicinal value purpose	Construction mat.	Timber production	Honey bee production	Fire wood	Improve soil fertility	Biodiversity conservation	Coffee bean yields size	Source of food for animal & human	Erosion control	Total	Rank
Albizia schimperia	0	3	4	5	3	5	5	4	0	4	33	9th
Milletia ferrugenia	5	4	5	5	5	5	4	5	2	2	40	3rd
Acacia abyssinica	0	5	5	4	5	5	5	4	3	4	30	10th
Vernonia amygdaline	5	5	0	4	2	5	4	4	3	5	37	6th
Pouteria adolfi	0	5	5	4	4	4	4	4	3	3	36	7th
Albizia gummifera	5	5	3	3	5	5	5	5	2	4	42	1st

Corton macrostchyus	5	5	2	4	5	3	3	4	3	5	39	4th
Sasbania sasbine	0	2	0	0	3	5	4	4	4	2	34	8th
Cordia africana	5	5	5	3	4	4	4	3	5	3	41	2nd
Schefflera abyssinica	0	2	1	5	4	4	5	4	3	2	38	5th
Total	25	39	30	38	47	45	40	42	28	37		
Rank	10th	5th	8th	6th	1st	2nd	4th	3rd	9th	7th		

Native shade tree species naturally regenerated in agroforestry practices are managed less intensively but still serve multiple utilities, not only for direct consumption such as fuel and construction materials but also for ecosystem services such as shade and as windbreaks, soil fertility enhancement, and soil erosion control (Biggelaar and Gold, 1996). Accordingly, farmers sustain trees in their coffee farms not only for shade but also for additional functions such as fruit, firewood, or honey production (Sota–pint *et al.,* 2007; Diriba *et al.*, 2011). Under careful management systems, shade trees provide substantial income to the coffee growers in the form of timber, firewood, edible fruits, and so forth (Tscharntke *et al.*, 2011). Shade trees also contribute to biodiversity conservation Perfecto *et al.* 2005; Soto pinto *et al.* 2000, erosion control, carbon sequestration Harmand *et al.,* 2007, soil fertility amendment through nitrogen fixing, microclimate modification (Bhagwate *et al*., 2008) Diriba *et al*. 2008) .

4. CONCLUSION

Coffee farmers in the study district have been cultivating coffee plants under the shade of important tree species. Hence, farmers have accumulated an excellent knowledge of the socioeconomic and ecological benefits of coffee shade trees. In general, the survey identified a set of shade trees species considered to be the most important to local communities including *Albizia gummifera, Acacia abyssinica, Albizia schimmperia Milletia ferruginea, Albizia grandibracteata Cordian africana Corton macrostachyus Pouteria adolififriederici, Vernonia amygdalina, Sesabania sesban* that are well adapted with coffee tress. However, farmers considered as preferred coffee shade trees species by characteristics were mainly based on tree height, fast decomposition rate, small deciduous compound leaves, and umbrella crown shape and tree root depth. Shade tree improve soil fertility and moisture, reduces undesirable environmental stress on coffee plants by ameliorating adverse climatic conditions, increase coffee tree longevity, reduce soil erosion, increase coffee yield and quality and reduced weeds and grasses. Moreover, farmers in study area have good experience in management of shade tree canopy for optimum coffee production. They employ pruning, mulching, thinning, weeding and hoeing, debarking and intercropping to manage shade trees in their coffee farm.

Based on the findings of this study, the following statements were recommended: Coffee shade tree has a huge socioeconomic and ecological benefit for coffee farmers. Therefore, training on maximized the most common useful coffee shade trees, their management 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.

Conflicts of interest

The authors declare that they have no conflicts of interest.

ACKNOWLEDGEMENTS

I would like to thank the Ethiopia Biodiversity Institute; Mettu Biodiversity Center for the financial support funding that made this data collection. The authors also gratefully thank the coffee farmers of the Yayo District, specially Aciboo, Geri, Wutate and Waabo kebele who responded to all questions with tolerance and Dr Fekadu Gurmessa for his useful suggestions and constrictive comment on methods of data interpretation.

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Appendix: 1 Most Desirable Tree to Serve as Coffee Shade in the Study Area

No	Botanic name	Family	Localname (Afan oromo)	Characteristic of coffee shade trees					
				Height	Leaf size	Crown size	Decomp. Rate.	Deciduousness	Coffee yield & quality
1	*Acacia abyssinica* Hochst.ex Benth.	Fabaceae	Lafto	Tall	Small	Wide	Fast	Yes	High
2	*Acacia albidia*	Fabacea	Sondo	Tall	Small	Wide	Fast	Yes	High
3	*Albizia grandibracteata* Taub.	Fabaceae	Ambabesa- arba	Tall	Small	Wide	Fast	Yes	High
4	*Albizia gummifera* (J.F.Gmel.) CA.Sm.	Fabaceae	Ambabesa-muke	Tall	Small	Wide	Fast	Yes	High
5	*Albizia schimperiana* Oliv.	Fabaceae	Ambabesa- adi	Tall	Small	Wide	Fast	Yes	High
6	*Bersama abyssinica* Fresen.	Melianthaceae	Lolchisa						
7	*Celtis africana* Burm.	Ulmaceae	Qe'o	Tall	Small	Medium	Medium	Yes	Medium
8	*Cordia africana* Lam.	Boraginaceae	Wadesa	Tall	Large	Wide	Medium	Yes	High
9	*Croton macrotachyus* Hochst.ex Del.	Euphorbiaceae	Makanisa	Tall	Large	Wide	Fast	Yes	High
10	*Entada abyssinica Steud.exA.Rich*	*Fabaceae*	Ambelta	Tall	Small	Wide	Medium	Yes	Medium
11	*Erythrina brucei*	Fabaceae	Walensu	Medium	Large	Wide	Fast	yes	High
12	*Ficus sur* Forssk.	Moraceae	Arbu	Tall	Large	Wide	Medium	Yes	Medium
13	*Ficus vasta* Vahl.	Moraceae	Qiltu	Tall	Large	Wide	Medium	Yes	High
14	*Millittia ferruginea* (Hochst) Bak.	Fabaceae	Askira/sotalo	Tall	Small	Wide	Fast	Yes	High
15	*Pouteria adolfi friederici* (Engl.) Baehni	Sapotaceae	Kararo	Tall	Small	Medium	Fast	Yes	High
16	*Ricinus communis L.*	*Euphorbiacea*	Kobo	Medium	Medium	Wide	Medium	Yes	Medium
17	Sapium ellipticum Hochst. Ex Krauss Pax	Euphoribiaceae	Bosoka	Tall	Medium	Wide	Medium	Yes	Medium
18	*Schefflera abyssinica* (A. Rich) Harms.	*Araliaceae*	Gatama	Tall	Small	Medium	Medium	Yes	High
19	*Sesbania sesban* (L.) Merr. Vaca Chiov.	Fabaceae	Sesbaniya	Short	Small	Small	Fast	Yes	High
20	*Syzygium guineense* (Willd.) DC.	Myrtaceae	Badesa	Small	Small	Medium	Slow	No	Medium