

Determinants of Arabica Coffee Yield and Farmers' Preference to Shade Trees Species at Jimma Zone, Southwestern Ethiopia

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Abstract

Coffea arabica L. is one of the major economically important crops grown in the southwestern part of Ethiopia. However, the productivity of coffee is very low in the region. The main aim of the study was to assess the determinants of arabica coffee yield and farmers' preference to shade tree species in Jimma zone, Southwestern Ethiopia. Two districts (Chora Botor and Limu Kossa) were selected purposively out of nine coffee-growing districts in Jimma zone. Three kebeles from Chora Botor and five kebeles from Limmu Kossa were randomly selected to run the household survey (399 randomly selected coffee growers). The collected data were analyzed using SPSS and STATA software. Ordinary Least square (OLS) regression models were implemented to resolve the determinant of coffee yield. The results indicated that socioeconomic and biophysical factors such as gender, education level, family size, coffee-growing experience, coffee farm size, weed management practices, disease, and insect pests were found to be determinants of coffee yield. Although the scale of shade tree preferences varies, farmers prefer coffee shade trees that have long heights, wider crown shapes, and evergreen leaves throughout the growing season. Accordingly, the ranking analysis in both districts indicated that Albizia gummifera, Acacia abyssinica, and Millettia ferruginea were the greatest preferred coffee shade tree species by farmers of the study area. Hence, improving the capacity of farmers about coffee farm management skills and promoting the use of preferred coffee shade trees should be strengthened to improve the coffee yield and quality in the region.

1. Introduction

Arabica coffee is one of the major cash crops and shade-loving plants, which is naturally growing as an under-story shrub in its original ecology in tropical high rain forests (Paulos and Tesfaye, 2000). In Ethiopia, coffee is traditionally cultivated underneath the cover of different shade tree types (Gole, 2003). Coffee farmers in Ethiopia have full local awareness of diverse shade tree types produced in their farmlands. Farmers identify the physical, biological and phenological characteristics and relations between tree type cover and components of the farmstead which is acquired through long years of experience and congenital local knowledge (Santo-Pinto et al., 2007).

The farmers around the southwestern part of Ethiopia are extremely reliant on coffee production. Because a large amount of their land is covered with this crop. From Oromia regions, Jimma zone which is found in the southwestern part of Ethiopia is the major coffee producing area. The Oromia Region has about 242,818.08 ha. of coffee land-dwelling of this, 18,028.87 ha of coffee is cultivated in Jimma zone. About 155,713.65 quintals of coffee are annually produced in the area (CSA, 2020/21). From the total revenue, about seventy-seven percent (77%) share is from coffee growing districts of Jimma zone. In another way, greater than sixty-nine percent (69%) of the area is land sited to coffee produce (Diro and Erko, 2019). This implies that coffee is the basis of their cash revenue and the means of living for farmers of around there.

In the past two decades, coffee preproduction folded two ways in Ethiopia. However, the productivity of coffee remains low compared with the highest coffee producers similar to Vietnam and Brazil (Kikkawa, 2018). Factors such as poor tree management practices, low productivity of aged coffee trees, loss of soil fertility and the increasingly unpredictable weather status, shade tree species, and its density are the ones attributing to the low productivity (Abu, 2015).

The changes in climatic conditions are also forecast to severely influence the population dynamics and the status of agricultural insect pests and disease development. The rising in temperature has a strong and direct influence on insect development, reproduction, and survival (Ward and Master, 2007) which directly or indirectly affects the yield of coffee.

The production of coffee is determined by extreme concentration of light, extreme temperature, and little soil moistness. Therefore, planting shade trees is in the coffee an indispensable approach, especially for Arabica coffee (Ashenafi et al., 2014). The advantages of using shade trees, especially under suboptimal conditions include modifying the micro-climate such as buffering temperature extremes in the air and soil and maintaining soil fertility through the incorporation of organic matter from leaf litter and pruning (Beer et al., 1998). By regulating light transmission to coffee plants which regulate coffee yields, shade trees can also extend the life of the coffee plantation (Beer, 1987). Staver et al. (2001) found that at low-elevations, dry coffee zone, the use of 35 to 65% shade promoted leaf retention in coffee plants during the dry season. Denser shading resulted in lower yields and under full sun, fruit quality decreased. An evaluation worked in Costa Rica on preferences of shade tree types disclosed that coffee growers' choice on tree maintenance in their farmland depends on tree characteristics like the rate of leaf rotten, tallness of the tree species, crown shape, and width (Albertin and Nair, 2004). Farmers also hold shade trees for other uses such as firewood, beehive hanging, fruits, and timber production (Muleta et al., 2011; Sato-Pinto et al., 2007).

Although coffee is cultivated under a variable mix of shade tree species in Ethiopia in general and in Jimma zone in particular, farmers usually select and maintain some shade tree types for their coffee and they eliminate the remaining that they consider as it has a greater influence on the coffee production and yield. Studies also showed that coffee production and productivity are extremely associated with the amount and dimensions of the branches of shade tree species (Bote and Struik, 2011). From all the shade tree species that originated in various coffee farmsteads in Ethiopia, very small types of shade trees are chosen in farmers' coffee farms and even in state farms.

All shade tree species have their own benefits regarding the improving Biological, physical, and chemical properties of the soil and in boosting the production and productivity of coffees produced beneath their covers. Nevertheless, very insufficient is known about coffee shade tree preferences and selection criteria by coffee farmers that exactly indicate the appropriateness and compatibility of shade tree species with coffee. Further, there is a knowledge gap how shade tree species and associated socioeconomic and biophysical factors affect coffee yield and quality. Consequently, this assessment was designed to

evaluate farmers' preference to coffee shade trees and determine factors affecting coffee yield in Jimma Zone, southwestern Ethiopia.

2. Materials And Methods

2.1. Description of the study areas

The assessment was worked in two major coffee-produced areas of Jimma zone namely, (Chora Botor & Limu Kossa), Southwestern Ethiopia (Fig. 1) in 2021. Chora Botor site is located at 7°59'N & 36°45'E at 1300–1400 meters above sea level (m.a.s.l.), The district has an annual mean minimum and maximum temperatures of 14°C and 28°C respectively and annual mean rainfall of 1680 mm. It is bounded with Limmu Kossa district in the south and Botor Tolay district in the North. Chora Botor is 461 kilometers from Addis Abeba and 105 kilometers from Jimma town. The soil of the area is characterized as Nitisol and Black type, with pH ranging from 4.5–6.0 (Mekonnen and Belehu 2007).

The Limu Kossa district is geographically located between 7°50' to 8°36' north latitudes and 36°044' to 37°029' east longitudes at 1200 to 3020 m.a.s.l. It is bordered with Limu Seka district in the north, Manna and Kersa districts in south, Buno Bedele zone and Gomma district in the west and with West Shewa Zone in northeast, with Tiro Afeta in southeast. It is situated in the north central part of Jimma zone. The mean annual temperature of the Limu Kossa district ranges from 18–23 °C. The mean annual rainfall of the district ranges from 1300–2300 mm. Maize and coffee are the main crops grown in the district (Diro and Erko, 2019). Limu Kossa is 409 kilometers from Addis Abeba and 55 kilometers from Jimma town. The soil of the area is characterized as a Eutric Nitisol, with pH ranging from 4.5–6.9 (Mekonnen and Belehu, 2007).

According to the 2007 national census, Chora Botor district has a total population of 91,738, of whom 46,454 were men and 45,284 were women; 1,043 or 1.14% of its population were urban dwellers. Most of the inhabitants were Muslim, with 65.26% of the population, while 29.27% of the population followed Ethiopian Orthodox Christianity, and 4.94% were Protestant. About 41% of the land area is cultivated of which 1973 ha (4.4%) is pastureland; 2111 ha (4.6%) is under forest; 4447 ha (9.8%) is irrigated land; and 18229 ha (40%) coffee (Population and Housing Census, 2007). The income of most of the populations in the study area is a diverse agricultural system where coffee is a significant contributor to the people's livelihood. Whereas the total population of Limu Kossa district is 161,338, of whom 81,462 were men and 79,876 were women; 14,842 or 9.2% of its population were urban dwellers.

In Limu Kossa, majority of the inhabitants were Muslim, with 72.6% of the population, while 24.41% of the population followed Ethiopian Orthodox Christianity, and 2.72% were Protestant. A survey of the land in this district shows coffee is an important cash crop. Over 50 square kilometers are planted with this crop. And 34.9% is arable or cultivable (24.6% was under annual crops), 20% pasture, 39.7% forest, and the remaining 15.4% is considered degraded or built-up areas. Fruits and sugar cane are important cash crops.

The study districts were nominated purposively based on the agroforestry production system and different coffee varieties are produced with various shade tree species in the area. There are 12 kebeles (the smallest administrative unit of a district) in Chora Botor district (two towns and ten village kebeles). Of these, ten of them are major coffee producers under shade. In Limu Kossa district, 44 kebeles, 4 town and 40 village kebeles are found. Of these, 32 kebeles are known for major shaded coffee production. Therefore, eight (three kebeles from Chora botor and five kebeles from Limu Kossa) kebeles were randomly selected for the study from both districts.

2.2. Data source and methods of data collection

The various socioeconomic data collection tools (key informant interview, Focus Group Discussion, and household survey) were employed. The quantitative information was collected by using key informant interviews whereas quantitative data about coffee growers' preference for shade trees, farming experience, and other benefits of shade tree species were collected from the sampled households survey. Moreover, the household survey was used to identify the determinant of coffee yield in the region. Informal discussion was held with frontline extension personnel to identify kebeles to participate in surveys.

2.3. Household sampling size and techniques

Secondary data from district Agricultural and Rural Development Offices was gathered to make a thorough comparison of shade tree trend analysis and socioeconomic data. The information collected included 1) demographic and basic farm data, 2) shade trees and overall uses, 3) related to coffee agronomic practices and production systems, 4) shade tree management, and 5) factors affecting coffee yield through semi-structured interview schedules, key informants, and Focus Group Discussion to satisfy pre-determined objectives.

Many methods are there to evaluate the sample sizes of the households. These are survey data for small people intimating the sample size of related studies, used for published tables, and applying a formula to calculate a sample size (Israel, 2012). For this study, the simplified formula developed by Yemane (1967) and reviewed by Israel (2012) was used to determine the sample size.

Three stages of purposive random sampling techniques were employed to select the study population. In the first stage, the two districts (Chora Botor and Limu Kossa) were selected purposely based on the availability of well-established coffee farms in the zone. In the second stage, a total of eight sample kebeles (three from Chora Botor and five from Limu Kossa) were randomly selected based on major coffee-producing kebeles under shade from both districts. In the third stage, the farm households per kebeles were randomly selected to have a total of 399 farmer respondents using Yemane (1967) which is reviewed by Israel (2012). The sample sizes of each kebele were determined proportionally to the total household heads (Table 1).

To calculate sample sizes, Yemane (1967) provides a simplified formula.

$$N = \frac{N}{1 + N(e)^2} = \text{-----} \text{Equation - 1}$$

Where: n = the sample size, N = the population size, & e = the level of precision.

To determine the required sample sizes of this study is at 95% confidence interval, and a $\pm 5\%$ precision level was used for the questionnaire interview from the eight study kebeles.

Table 1
proportional sample sizes and total households of coffee producers in the kebeles

Kebeles	Total households	Sample size	Percentage (%)
Limu Kossa			
Dambi Gabana	1162	57	14.3
Dangajo Sole	1228	60	15.0
Gena Danbi	1210	59	14.8
Chaffee Ilfata	921	45	11.3
Kosa Geshe	705	34	8.5
Chora Botor			
Angalo Somo	700	55	13.8
Haro Lejiso	504	43	10.8
Mecha Dire	573	46	11.5
Total	6991	399	100.0

2.4. Key informants and Focus Group Discussion

For this study the farmers who has good understand and familiar about coffee shade trees, experienced in coffee production under different shade tree species, and farmer who lived for a long period of time in the area were used as key informant. From each kebele, at least five farmers were asked to identify and give the name of six key informants. Then the identified key information was ranked and the most frequently appeared top five farmers were used for key informant interviews.

Focus group discussions (FGDs) were held by an interviewer in a loosely structured discussion of various topics of interest with five groups based on interdisciplinary teams consisting of forestry, coffee agronomists, and socioeconomics. It includes group interviewing in a small group has six people.

2.5. Data analysis

The responses of the farmers collected by the questionnaires were coded and appeared to excel sheet. Data was grouped and sum up by response category on the datasheet. The Descriptive analysis was accomplished by using statistical packages for social science version 20 for windows (IBM SPSS Inc, USA) software computer program and the results were presented in the form of table and figures and quantitative analysis was done in STATA. The Ordinary Least Square regression model as given by Hayes and Matthes (2009) was used to analyse the determinants of the yield of coffee, as stated in the question below.

$$Y = b_0 + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4 + \dots + u \dots \dots \dots \text{Equation-2}$$

Where: Y = Productivity of coffee (Kg/ha); b_0 = Regression Intercept; $b_1, b_2 \dots b_8$ = regression coefficient: X_1, X_2, X_3, X_4, X_5 is continuous explanatory variables (Age of HH, Family size, Coffee growing experience, Coffee land holding, Age of coffee tree, respectively and u = error term.

3. Result And Discussion

3.1. Determinants of Yield of Coffee

Respondent characteristics such as gender, educational level, family size, coffee-growing experience, and landholding size are the major factors that influence coffee yield in the study area (Table 3). Most of the respondents (91%) were male-headed households (Table 2). The econometric model analysis result indicated that the sex of the households significantly ($P = 0.01$) determines the yield of coffee (Table 3). Keeping other factors constant, as the number of male-headed households increased, the coffee yield increased by 0.41%. Because female-headed households have no access to current information, modern technology, access to credit and extension services as that male-headed households. (Gebre et al., 2021; Kangile et al., 2021; Mohammedsani, 2014; Doss and Morris, 2000). They reported that females have less access to improved agricultural technologies and extension services, which contributes to lower adoption rates. Furthermore, male-headed households have better access to information than female households which helps in the adoption of improved agricultural technologies.

About one-third (34% and 27%) of the respondents completed their elementary education (5–8 grade) and were illiterate/uneducated, respectively (Table 2). Education level has shown a positive and significant relationship with the yield of coffee (Table 3). Farmers who are educated (who can read and write) tend to be more efficient in coffee production compared to farmers who are unable to read and write. Education level has a strong and important contributing factor to farmers' implementation of improved agricultural technologies (Gezahagn, 2019; Deressa et al., 2009; Nchare, 2007; Zemedu, 2004). Consequently, education and any learning or training is a vital factor for the farmers to understand and interpret the information coming from any direction to them. Farmers' education is also crucial to the effective work of promoting the extension services because if the farmers have a better education, they can have the capability to read and interpret easily the information transferred from the personnel to them. When they are educated enough, they are more competent in the management of the intensive systems of coffee

production and marketing. As a result, there is a need frequently to record-keeping on production activities, revenue, and expenses to properly exploit the benefit of the business.

Farmers in the study areas have long years of coffee farming experience (ranges from 5 to 60 years with an average of 21 years) (Table 2). The farming experience of the farmers is also an important determinant that influences the yield of coffee. The experience allows farmers to make better decisions that diminish crop disasters in terms of yield. The result showed that a 1% increase in farm experience leads to an increase in coffee productivity by 0.13% (Table 3). Farming experience over a long period of time aids the farmers to acquire great functional skills in the relationship between inputs and outputs and make good decisions in choosing appropriate input use. Consequently, farmers who have accumulated coffee farming experiences over a long period of time have better chances to intensify their coffee yield. Additionally, the farming experience of the farmers is also an important factor, which allows farmers to make better choices that decrease crop disaster in terms of both quality and quantity. Farmers with longer farming experience are expected to be more knowledgeable and skillful (Gezahagn, 2019; Senkondo et al., 2004).

The study areas have been known as one of the major coffee-producing areas where both small-scale and large-scale coffee plantation exists. The average land-holding capacity of the study areas is high compared to other major coffee-producing districts (like Gomma and Manna districts) in Jimma zone (Diro and Erko, 2019; Diro et al., 2016). The report revealed that the average coffee land holding size of the study area was 2.08 hectares (Table 2). The coffee landholding capacity has a negative relationship with coffee yield. The finding indicated that a 1% increase in coffee farm size tends to decrease coffee yield by 0.009% keeping other variables constant (Table 3). This suggests that excess land allocation for coffee production requires additional distribution of resources which may disgust and discourage farmers. This leads to a decrease in the production efficiency of coffee. The sign of the coefficient concurred with the different findings (Gezahagn, 2019; Mukasa and Salami, 2015; Oseni et al., 2015; Aguilar et al., 2014; Adesoji and Farinde, 2006; Minai et al., 2014; Njuki et al., 2006). However, this study contrasts with the outcomes of Gebre et al. (2021) who stated that an increase in farm size by 1% increases coffee output by 35% Holding all other factors constant /Ceteri paribus.

Most of the coffee trees in the farms were aged trees. The average age of coffee in the the study districts was 20.5 years (Table 2). There is a negative relationship between the age of coffee trees and the yield of coffee (Table 3). When the age of coffee trees increased by 1%, the productivity of coffee will be decreased by 1.05%. this indicates that the habit of keeping aged coffee trees beyond the productive aged is common in the study area. This charges the farmers by declining the yield of coffee.

The average family sizes of the households in the study districts were about 6. Whereas the maximum and minimum family size was 19 and 1, respectively (Table 2). The household family sizes have positive relationships with yield of coffee in the study districts (Table 3). In the study area, when the number of household family sizes increased by 1%, the yield of coffee will increase by 0.008%. The number of family members actively engaged in coffee production, and implementation of income diversification

through intercropping, training, and technical assistance had a positive and significant relationship with the productivity of coffee. The number of active family members in coffee production was found significant and has a positive relationship with the productivity of coffee. The findings revealed that the very single additional active member, the productivity of coffee increased by nearly eleven units if all other variables were constant (Table 3). The finding is relatively similar with the outcome of other research done in Ethiopia by different authors (Gebre et al., 2021; Bhattarai., 2020; Temesgen and Getachew, 2018). Their report discovered that productivity significantly increases with the increase in the number of active family members. The active member of the family offers incentive care, which is required for the coffee plant to produce a high yield. The significance of the number of active family members in coffee production highlights that farm labor is an important factor in affecting coffee productivity.

The study showed that intercropping the crops in the coffee farm is not practiced in both districts. About 84.9% of the respondents were not intercropping other crops with their coffee. Only 15.1% of the respondents were use the mixed type of coffee cropping system. It is obvious that to increase the production and productivity of crops fertilizers application is crucial. Subsequently, about 31.7% of the respondents used organic fertilizer for their coffee farms. Of the different organic fertilizers, about 68.3% of respondents apply compost, cow dung, and farmyard manure to their coffee farms (Table 2).

Table 2
Descriptive statistics for continuous and categorical variables

Descriptive statistics for continuous and categorical variables				
Continuous variables	Mean	Max	Min	SD
Age	41.39	68	20	12.26
Family size	6.22	19	1	12.93
Growing Experience	20.74	60	5	11.51
Coffee Landholding	2.04	8	1	1.07
Age of Coffee	20.52	60	5	11.11
Categorical variables				
Education Level		Number	Percent	
· Illiterate/ Uneducated		106.00	26.60	
· Model (1–4)		81.00	20.30	
· Elementary (5–8)		135.00	33.80	
· Secondary (9–12)		68.00	17.00	
· Diploma (10 + 3)		9.00	2.30	
Weeding				
· Yes		266.00	66.50	
· No		133.00	33.50	
Gender				
· Male		363.00	91.00	
· Female		36.00	9.00	
Shade Using				
· Yes		393.00	98.50	
· No		6.00	1.50	
Intercropping				
· Yes		59.00	15.10	
· No		340.00	84.90	
Fertilizer Application				
· Applied		123.00	31.70	
Where: Max-maximum; min-Minimum; SD- standard deviation				

Continuous variables	Mean	Max	Min	SD
· Didn't Apply		266.00		68.30
Insect				
· Antestia bug		6.00		1.60
· Stem Borer		298.00		74.60
· Berry Borer		67.00		16.80
· Leaf Minor		28.00		7.00
Diseases				
· Coffee Berry Diseases		281.00		70.30
· Coffee Leaf Rust		22.00		5.50
· Coffee Wilt Diseases		11.00		2.80
· Root rot		85.00		21.40
Where: Max-maximum; min-Minimum; SD- standard deviation				

The household survey indicated that two third (66.5%) of the coffee growers in the study area remove coffee weeds from their coffee farms (Table 2). Farmers who weed their coffee farms get more coffee yield than those farmers who don't weed their coffee farms (Table 3). Different nutrients and minerals, water, and light are competed by weeds. If weeds are allowed to grow during the late post-rainy season period, they use the soil moisture that coffee needs in the subsequent dry season. Proper control of weeds typically has a positive effect on the bean size and flavor of coffee (Wintgens, 2004). Because of the diversity of weeds and the environmental conditions in the coffee growing areas, however, dependency on single weed management is not advisable. Therefore, farmers in the study districts should control weeds from their coffee farms by a combination of different weed control methods. Integrated weed control (IWM) would be the best strategy for sustainable coffee production (Anteneh et al.,2010).

Coffee diseases and insect pests are also other factors that can affect coffee yield and even quality.

About 70.3% of coffee farmers found coffee berry diseases (CBD) as a major disease that affects coffee yield. When coffee berry diseases attack the fruits in its more advanced stage of growth cause severe damage to the yield and as well as quality of coffee (Eshetu and Girma, 2008). The remaining 21.4%, 5.5%, and 2.8% of the respondents found root rot, coffee leaf rust, and coffee wilt diseases, respectively. Similarly, farmers also mentioned that insect pests like stem borer, berry borer, antestia bug, and leaf miner were among the factors that decline yield on their coffee farm in both districts. About 74.6% and 16.8% of the respondents in the study areas face stem borer and coffee berry borer, respectively. Whereas 7.0% and 1.6% of respondents reported incidence of leaf minor and antestia bug, respectively. Study

results also showed that diseases like root rot, coffee leaf rust, coffee berry disease, insect pests like stem borer, berry borer and, leaf minor had a negatively significant effect on the productivity of coffee (Table 3). According to farmers consulted in the current study, the application of different cultural coffee management practices such as adding ash around coffee trees, burning diseased coffee trees, and killing the larvae manually by insects sticking into the hole burrowed by insects are traditionally exercised to control ants and stem borers. Further scientific studies on the effectiveness of these cultural methods of pest control are suggested to complement the farmers' traditional pest management knowledge with research-based control evidence. That will have a positive effect on the sustainable management of the major coffee pest and subsequently sustain coffee productivity.

Table 3
Ordinary Least square (OLS) regression model for coffee yield.

Yield per Ha.	Coefficient	Robust Std, Err	t	P > t
Age of HH	0.0020 ns	0.0013	1.5300	0.1270
Gender/Sex	0.4112***	0.1450	2.8300	0.0050
Education level	0.0517***	0.0043	12.0000	0.0000
Family size	0.0079***	0.0012	6.7800	0.0000
Growing experience	0.1263***	0.0328	3.8600	0.0000
Coffee landholding (ha)	-0.0087***	0.0014	-6.1000	0.0000
The average age of coffee	-1.0478***	0.1188	-8.8200	0.0000
Coffee intercropping	0.0169ns	0.0467	0.3600	0.7180
Weeding	0.4299***	0.1570	2.7400	0.0060
Fertilizer Application	0.0702***	0.0187	3.7600	0.0000
Shade using	0.5327***	0.1506	3.5400	0.0000
Insect				
<i>Antestia bug</i>	-0.9415	0.4852	-1.9400	0.0530
<i>Stem Borer</i>	-0.9614**	0.4665	-2.0600	0.0400
<i>Leaf minor</i>	-0.9577	0.5498	-1.7400	0.0820
<i>Coffee berry borer</i>	-0.8440	0.4570	-1.8500	0.0660
Diseases				
<i>Coffee wilt diseases</i>	-0.0706	0.1055	-0.6700	0.5040
<i>Coffee leaf rust</i>	-1.1468***	0.1270	-9.0300	0.0000
<i>Root rot</i>	-1.3208***	0.1205	-10.9600	0.0000
<i>Coffee berry diseases</i>	-1.7512***	0.1854	-9.4500	0.0000
_Constant	4.9284***	0.3924	12.5600	0.0000
<i>Number of observations</i>	399			
<i>F (19, 379)</i>	173.92			
<i>Prob > F</i>	0.0000			
<i>R-squared</i>	0.8971			

Yield per Ha.	Coefficient	Robust t	P > t
		Std, Err	
Adj R-squared		0.8919	

*, **and *** represent significance at 10%, 5% and 1% probability levels respectively.

Likewise, the coefficient of application of organic fertilizers is positive and significant, which implies that farmers who apply organic fertilizers to their coffee farms get more coffee yield than those farmers who don't. This is because coffee is a highly nutrient feeder naturally.

The assessment of the study revealed that almost all the interviewed farmers use shade trees for their farms to produce coffee. Of the whole respondents, about 98.5% of them use shade trees for their coffee production in both districts (Table 2). The respondents in a general idea of shade trees were extremely positive and having shade trees was mentioned as a precondition for planting coffee trees on their farms.

The coefficient of shade use was also positive and significant ($P = 0.01$). Therefore, the coefficients of using shade trees for coffee production, indicate a 1% rise in using shade trees leads to an increase in coffee productivity by 0.53% (Table 3). The respondents also indicated that growing coffee under shade trees has many advantages i.e; improving soil fertility, increasing production and productivity, protects the coffee from the heavy sun and rain.

Planting shade trees on the coffee farm helps to safeguard the coffee plants from adverse environmental conditions like excessive sunlight, frost hail, and surplus wind speed. Coffee shade trees are crucial to shelter the newly planted coffee seedlings from undesirable environmental stress that make them stunted growth and wilted. They were also protective coffee plants from adverse climatic conditions during their flowering and fruiting stage. They improved the climate for coffee plants by protecting extreme temperatures in the air and soil and by lowering wind velocity in coffee farms. (Emire and Asfaw, 2018; Aduugna and Paul, 2014 Santos et al., 2012; Claudia, 2010; Albertin and Nair, 2004).

3.1. Farmer's Preference to shade tree species

The assessment of the study showed that the major shade tree species growing in both districts *were* *Acacia abyssinica*, *Albizia gummifera*, *Cordia Africana*, *Grevillea robusta*, *Millettia ferruginea*, *Erythrina abyssinica*, and *Croton macrostachyus* (Fig. 2). The current findings are similar to Sualeh et al. (2022) they reported *Albizia species*, *Croton macrostachyus*, *Cordia Africana*, *Acacia abyssinica*, *Millettia feruginea*, *Ficus vasta* and *Grevillea robusta* are the most usually expanded shade tree species in the study area.

The respondents in the study area have a deep knowledge of preferences of companionable shade tree species with coffee plants. From the usually growing shade tree species in both districts, *Albizia gummifera*, *Acacia abyssinica*, and *Millettia ferruginea* were the three top preferred shade tree species by farmers. Farmers prefer these shade trees because of their multiple advantages. These shade trees have

high compatibility with coffee trees and wider canopy cover (crown) that provide better shade to coffee plants. Most of the coffee growers in Chora Botor (95.1%) and Limu Kossa (90.6%) districts showed more preference for coffee shade trees that have wider crown types (spreading types; like *Albezia gummifera* and *Acacia abyssinica*) than compact or narrow crown types (Table 5). Coffee shade trees that have the spreading type of crown shade provide better shade to coffee plants than the narrower one. They are also more important when there are sparsely distributed shade trees in coffee farms as they cover more areas. Coffee shade trees that have spreading types of crown shapes also allow light to filter onto the coffee trees. They have also small size leaves compared to other shade trees like *Ficus vasta* which has a larger leaf size. (. Almost all farmers at Chora Botor Limu Kossa (97%) prefer shade trees having small leaf sizes because smaller leaves produced smaller droplets when it rained and therefore caused less erosion, and the larger leaves are not easily decomposed as those smaller leaves. Farmers in the southern part of Ethiopia, also prefer well-suited shade tree species such as *Ficus sur*, *Millettia feruginea*, *Cordia Africana*, *Albizia gummifera*, *Croton macrostachyus* and *Vernonia amygdalina*, *erythrina abyssinica* (Emire and Asfaw, 2018; Ashenafi et al., 2014).

In the study site, coffee producers had long experience growing coffee plants under different shade tree species. Their overall impression of shade was very positive, and they believed shade was a precondition for coffee production systems. About 100% of the respondents in the area mentioned that shade trees found in their farms were older than 10 years (Table 4).

Table 4
Shade tree species characteristics at Limu Kossa and Chora Botor districts, Jimma Zone,
Southwestern Ethiopia

Shade trees characteristics	Location					
	Limu Kossa		Chora Botor		Overall	
	(f)	(%)	(f)	(%)	(f)	(%)
The average age of shade tree species						
About 10 years	7.00	4.90	11.0	4.30	18.0	4.50
Between 11to 20 years	26.0	18.3	41.0	16.1	67.0	16.9
Between 21 to 30 years	25.0	17.6	44.0	17.3	69.0	17.4
Greater than 31 years	84.0	59.2	158	62.2	242	61.1
Importance of shade trees						
Improves soil fertility.	2.00	1.40	7.00	2.80	9.00	2.30
Increases productivity.	3.00	2.10	12.0	4.80	15.0	3.80
Protects coffee from heavy sun.	136	95.1	227	90.4	363	92.1
b/c of their compatibility to coffee	1.00	0.70	2.00	0.80	3.00	0.80
For Construction	1.00	0.70	1.00	0.40	1.00	0.30
Other	0.00	0.00	2.00	0.80	3.00	0.80
Major shade tree species in coffee farms						
<i>Albezia gummiifera</i>	34.0	23.6	49.0	19.2	83.0	20.8
<i>Acacia abyssinica</i>	42.0	29.2	52.0	20.4	94.0	23.6
<i>Cordia africana</i>	15.0	10.4	39.0	15.3	54.0	13.5
<i>Millettia ferruginea</i>	6.00	4.20	24.0	9.40	30.0	7.50
<i>Erythrina abyssinica</i>	6.00	4.20	13.0	5.10	19.0	4.80
<i>Croton macrostachyus</i>	24.0	16.7	43.0	16.9	67.0	16.8
<i>Gravilia robusta</i>	17.0	11.8	35.0	13.7	52.0	13.0
Shade tree species under which coffee yield increased						
<i>Albezia gummiifera</i>	64.0	44.4	123	48.2	187	46.9
<i>Acacia abyssinica</i>	66.0	45.8	75.0	29.4	141	35.3

Where: f-frequency

Shade trees characteristics	Location					
	Limu Kossa		Chora Botor		Overall	
	(f)	(%)	(f)	(%)	(f)	(%)
<i>Cordia africana</i>	3.00	2.10	14.0	5.5	17.0	4.30
<i>Millettia ferruginea</i>	10.0	6.90	35.0	13.7	45.0	11.3
<i>Erythrina abyssinica</i>	1.00	0.70	8.00	3.1	9.00	2.30
Where: f-frequency						

Coffee growers in Chora Botor and Limu Kossa districts prefer indigenous trees over exotic shade trees for their coffee (Table 5) for two main reasons: the long year of experience the farmers have in growing and using indigenous trees and the better adaptability of indigenous trees to the climate of the area over exotic ones. Coffee growers in Chora Botor (63.9%) and Limmu Kossa (77.3%) districts also prefer longer (> 15 m) shade trees for their coffee production (Table 5). Longer shade trees provide adequate sunlight to coffee plants so that the photosynthesis capacity of the plant would be improved. They can be also used for hanging beehives for honey production and timber production. However, coffee growers prefer shorter shade tree species on their coffee farms than longer shade tree shade trees in Costa Rica (Albertin and Nasir, 2004; Samuel, 2012). The reason could be the management for smaller shade tree species are simple and has less damage to coffee plants from different tending operations; shorter shade trees cause less erosion from droplets than taller shade trees.

Table 5
Shade Tree preference of coffee growers in Limu Kossa and Chora Botor districts, Jimma
Zone, Southwestern Ethiopia

Shade preference	Location					
	Chora Botor		Limu Kossa		Overall	
	(f)	(%)	(f)	(%)	(f)	(%)
Types of shade trees preferred						
Indigenous trees	141	96.5	248	97.2	389	97.7
Exotic trees	0.00	0.00	0.00	0.00	0.00	0.00
Does not matter.	3.00	3.50	7.00	2.80	10.0	2.30
Shade Trees height preferred						
Short (< 5m)	2.00	1.40	7.00	2.70	9.00	2.30
Intermediate (10-15m)	50.0	34.7	51.0	20.0	101	25.3
Tall (> 15m)	92.0	63.9	197	77.3	289	72.4
Shade Tree crown preferred						
Spreading (wide) types of shade trees	137	95.1	231	90.6	368	92.2
Compact types of shade trees	7.00	4.90	20.0	7.80	27.0	6.80
Intermediate types of shade trees	0.00	0.00	4.00	1.60	4.00	1.00
Shade tree leaf size preferred						
Shade trees have small leaf sizes.	141	97.9	249	97.6	390	97.7
Shade trees have large leaf sizes.	3.00	2.10	6.00	2.40	9.00	2.30
Shade trees with medium leaf size	0.00	0.00	0.00	0.00	0.00	0.00
No effect	0.00	0.00	0.00	0.00	0.00	0.00
Shade trees type preferred						
Deciduous trees	18.00	12.5	63.0	24.7	81.0	20.3
Evergreen trees	118	81.9	190	74.5	308	77.2
Both	8.00	5.60	2.00	0.80	10.0	2.50
Where: f-frequency						

Most of the coffee growers at Chora Botor (81.9%) and Limu Kossa (74.5%) preferred evergreen shade tree species to deciduous types (Table 5), because of several advantages that evergreen shade trees can

provide. To protect coffee plants from dangerous sunlight, especially throughout the dry season, evergreen shade tree species are the best. During the dry period, evergreen species are also used as animal feed. During the long dry season, the deciduous shade tree species shade out their leaves and then expose the coffee plant to extreme sunlight which directly affects the growth and development of the coffee plant.

Conclusion

The main objective of this study was to assess the preference for coffee shade trees and the associated factors influencing the yield of coffee in Southwestern Ethiopia. Socioeconomic and biophysical factors such as gender, education level, family size, coffee-growing experience, coffee farm size, weed management practices, disease, and insect pests were the major factors that influence coffee yield in the study site. The coffee farmers in the study areas had long experience in growing coffee under different shade tree species. Their general sense of shade was quite positive, and they believed shade as a precondition for the coffee production system. The scale of shade tree preference of farmers, however, was variable and mainly considered shade tree height, crown shape, and evergreen/ deciduous characteristics of shade tree species. Accordingly, farmers in the study area prefer *Albizia gummifera*, *Acacia abyssinica*, and *Millettia ferruginea* as a top tree for coffee production suggesting that selection of shade tree species for coffee

plantations in the future should take farmers preferences criteria and their knowledge into account. Therefore, policy measures that improve the socioeconomic situations and capacity of the farming communities with regards to coffee farm management skills along with proper utilization of resources and technology that simplifies coffee farm activities will lead to sustain coffee yields over time.

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Figures

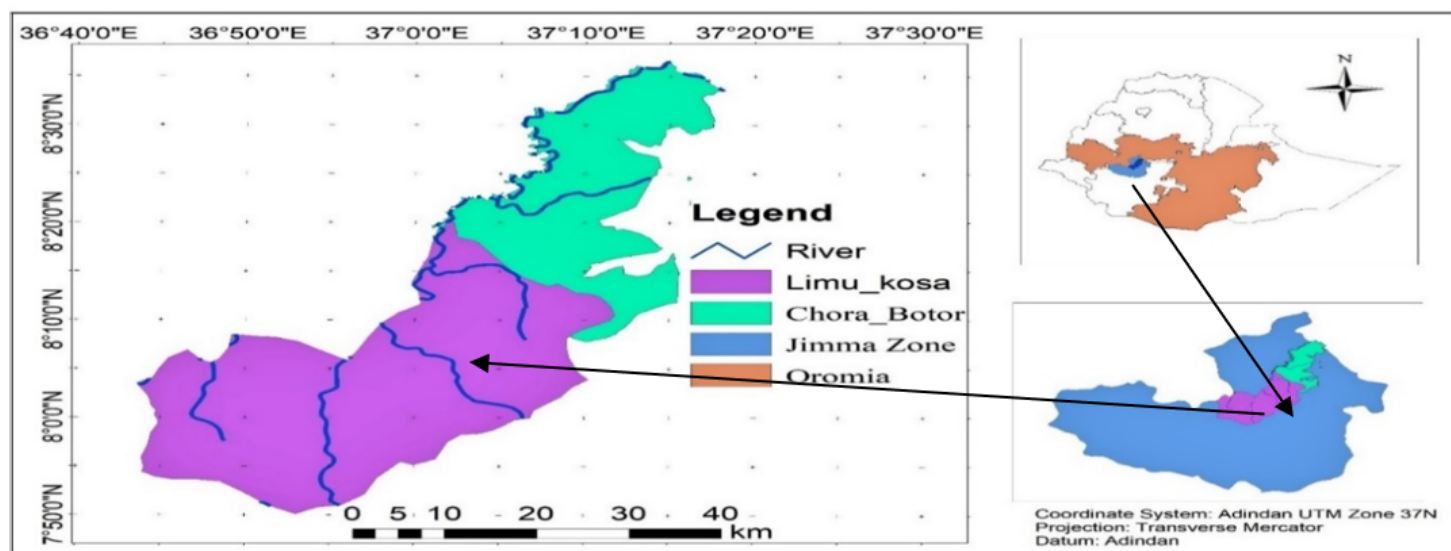


Figure 1

A map of study area.

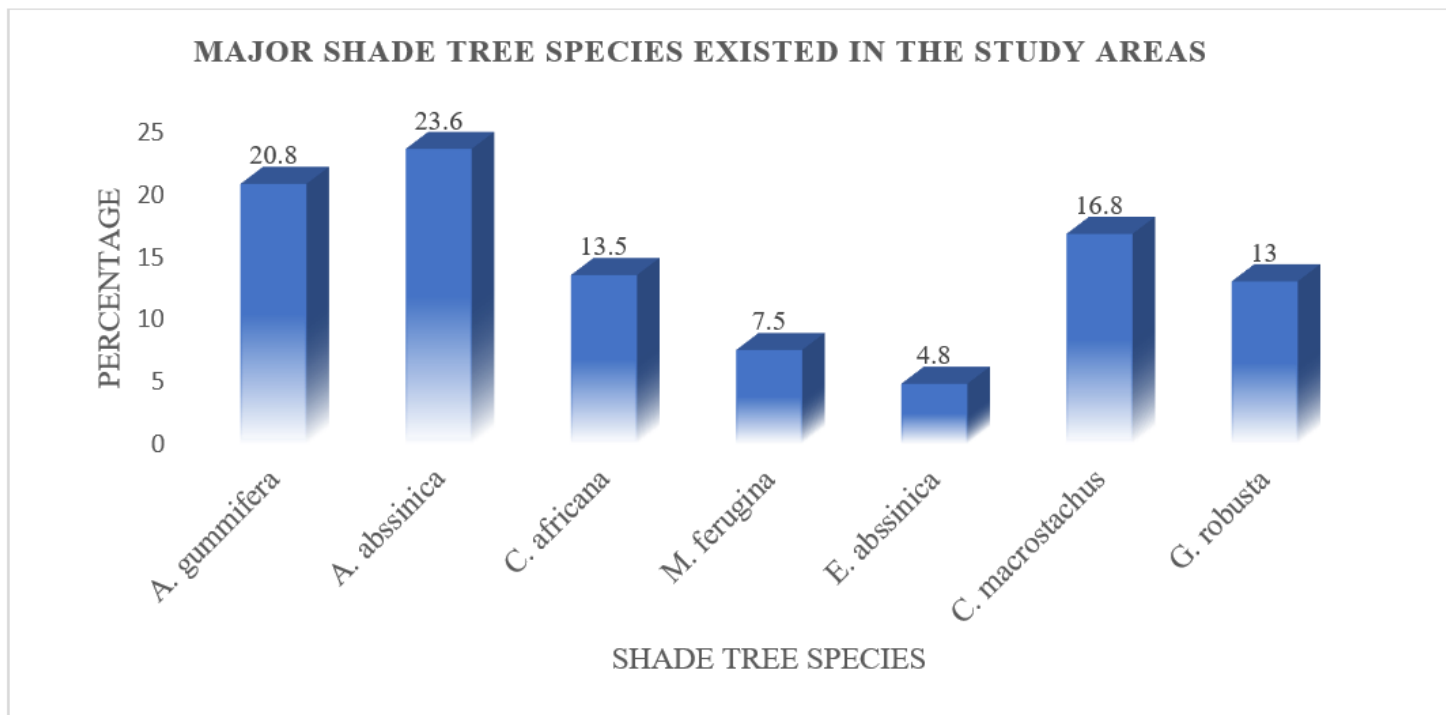


Figure 2

Major shade tree species existed in the study area.

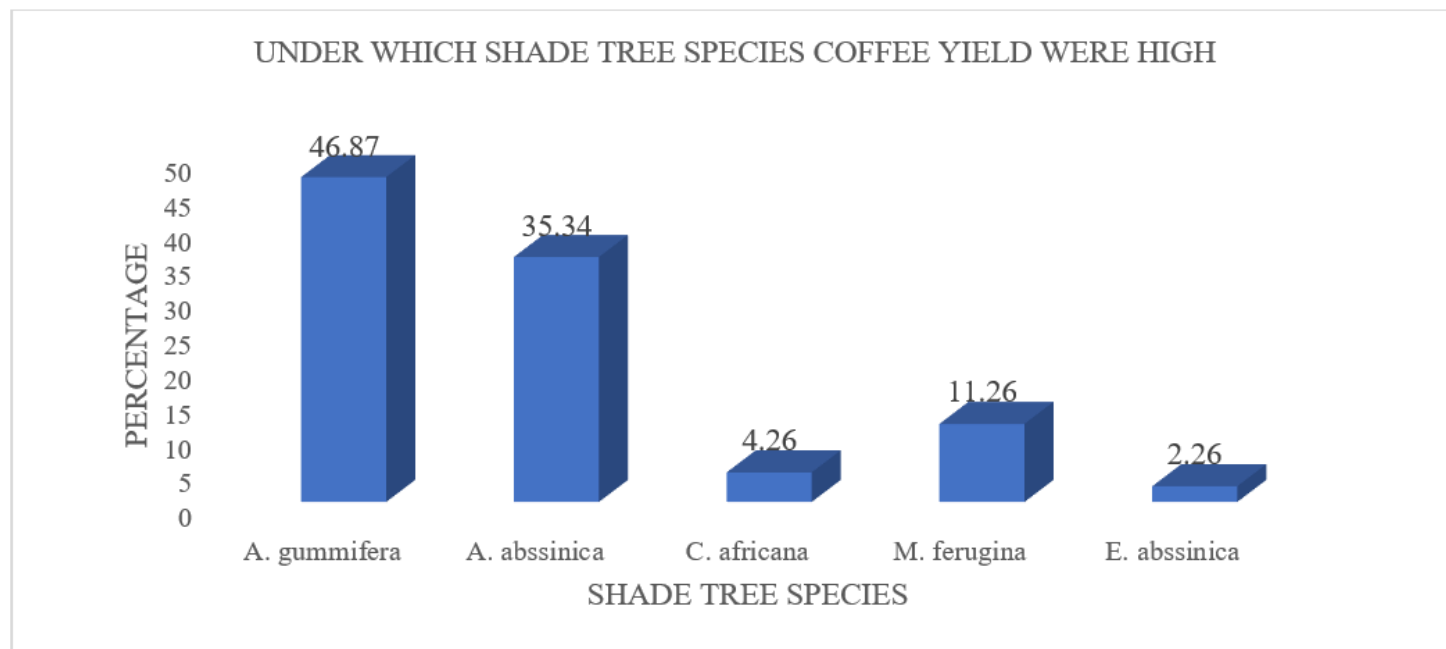


Figure 3

Shade tree species under which coffee yield was high at both districts