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Tree Species Diversity in Smallholder Coffee Farms of Bedeno District, Eastern Hararghe Zone, Oromia Regional State, Ethiopia

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Abstract: Although, Coffee agroforestry have a considerable contribution in supporting biodiversity, yet their contribution are insufficiently documented. Thus, this study was aimed to assess the diversity tree species in small holder coffee farms in Bedeno district, East Hararghe Zone, Oromia Regional State, Ethiopia. Eleven *kebeles* were selected purposively and four of them were randomly selected from which 119 households were selected, whose coffee farms used for Tree inventories in this study. The study was carried out in between October 28, 2019 and April 15, 2020. Data was analyzed by Statistical Package for Social Sciences (SPSS) version 20 and Microsoft Office Excel 2010, using descriptive statistics such as means, percentages and frequency. A total of 53 tree species representing 28 families, constituting 69.8% indigenous and 30.2% exotic tree species were recorded in the current study coffee farms. The result of this study shows significant difference ($p<0.05$) between three wealth categories across four study *kebeles* and tree species diversity of coffee farms influenced by wealth status of the household. The rich class owned more diversified tree species. The highest and lowest mean value of richness (11.5, 3), Shannon index (2.3, 0.9) and abundance (22.8, 4.8) were recorded on the farm of rich and poor household respectively. There was no significant difference among the study *kebeles* and the position of *kebeles* was not influenced tree species diversity in this specific study. Therefore, traditional shade based coffee production system should be encouraged for tree species diversity conservation in smallholder coffee farms.

Keywords: Coffee, Richness, Smallholder Farmer, Tree Diversity, Wealth Classes, Bedeno

1. Introduction

Deforestation and the consequent losses of biodiversity are the top global environmental problems [12, 24], which threaten biodiversity and ecosystem services [23]. Although, Agriculture is a major livelihood for millions of people in the world, widespread agricultural expansion with population growth is one of the major causes of deforestation, land degradation and biodiversity loss [10, 5, 18], which is primarily a concern for the developing countries of the tropics [52]. Across the tropics, large areas of forest have been destroyed, fragmented and converted to other land use [29]. Particularly, it is ongoing issue [55], resulting in destructions of more than 150,000 hectares of forest land annually in Ethiopia [51].

Ethiopia faced biodiversity losses [51], extinction, changes to climatic conditions, desertification and displacement of indigenous people [55]. Therefore, Many species may be lost before they are even known to science in different regions of the world [18]. Agro-ecosystem-based biodiversity conservation has received considerable attention as a supplement to the conventional conservation methods following the continued contraction of natural ecosystems [12, 5] and may necessarily play important roles in conserving biodiversity [11, 23, 21]. More than 90% of tropical biodiversity is found in human-modified landscapes, outside protected areas [16, 23]. Thus, coffee based Agroforestry systems [25, 2, 26], home-gardens and plantations [23] can serve as biodiversity refugia.

Coffee based Agroforestry is one way of biodiversity conservation by having high species diversity and incorporation of diverse native species and enhanced habitat and landscape heterogeneity [23, 21]. Accordingly, the presence of 47 species in coffee farms [5], 36 tree species [19], 29 tree species [40, 21] and 34 tree species [59], in smallholder coffee farms. Shaded coffee systems also provide a range of supportive, regulatory, provisioning ecosystem services including: fruits, firewood and local construction material to smallholder coffee farmers [56] and conserve soil by increasing soil fertility and reducing nutrient leaching [21]. Therefore, shade grown coffee is increasingly promoted as a promising approach to deal with the twin challenges of biodiversity conservation and local development [28].

Traditionally, coffee is grown under varieties of shade trees species [32, 45], which is a common practice in smallholder coffee farms in Ethiopia [13, 22, 7]. In many parts of Ethiopia, coffee is grown mainly as understory of evergreen natural forest and under managed coffee based agroforestry system [3]. Hence, coffee production is associated with other plant species which serve as shade trees [53]. Understanding the diversity and management of coffee shade trees is important to maintain the balance of coffee agro-ecosystem productivity and ecological functions and to improve biodiversity conservation including, the conservation of native tree species [20]. However, there are only few studies of biodiversity in human made landscapes such as coffee agro-ecosystems have been conducted in Africa [33] including Ethiopia, in which a very few systematic studies done on tree selection criteria and management practices [31].

Bedeno district, (the study area) is one of the seven major coffee producing district of East Hararghe zone of Eastern Ethiopia [41], in which coffee production is predominated by small scale farming activity. The other six major coffee growing districts are Malka Bal'o, Dader, Kurfachalle, Gurawa, Kombolcha and Gursum [41]. Cultivating coffee under varieties of shade tree species is common practice in smallholder coffee farms in the study area. It looks like that smallholder's coffee farms of this area have also a considerable contribution towards tree diversity conservation similar to other coffee producing regions of the world. However, there was no study which documented tree species diversity, preference and management practices in smallholder's coffee farms in the current study area. Therefore, the objective of this study is to assess diversity of tree species in smallholder coffee farms in Bedeno, East Hararghe Zone, Oromia Regional State, Ethiopia.

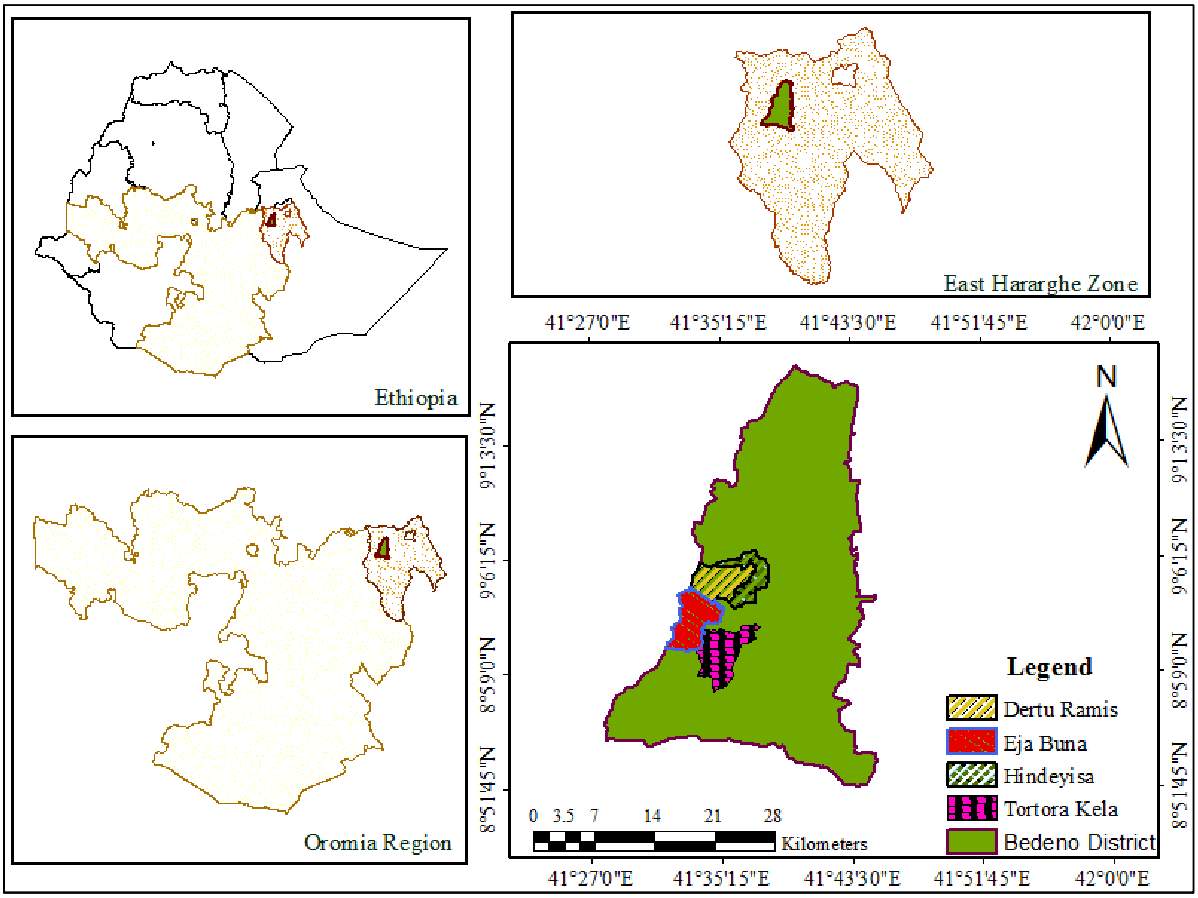

Figure 1. Location map of the study area (Bedeno District).

2. Materials and Methods

2.1. Description of the Study Area

The study was conducted in Bedeno district, Eastern Hararghe Zone of Oromia Regional State, Ethiopia. Bedeno is geographically found at 8° 49' 18" - 9° 35' 28"N Latitude and 41° 12' 0" - 42° 3' 15"E Longitude (Figure 1). The District is located 107 km to the West of the capital city of East Hararghe Zone, Harar City, covering an area of 974.10 km^2 which accounts for about 3.89% of the total area of the Zone [15].

The total populations of Bedeno district are 238,966 from which 120,521 are male and 118,445 are female with the density of 245 persons per square km. Bedeno is the third most populous district in East Zone by covering about 8.8% of Zonal population [17]. The district is subdivided into 42 *Kebele* Administrations, categorizing in to 40 Rural and 2 small urban *Kebeles*. The total rural households are 37681 from which are 34676 male and 3005 are female headed [15].

The district is mainly characterized by rugged terrain plateaus, mountainous hills, valleys and gorges with the altitude that ranges from 1200 and 3109 m.a.s.l. with the Agro-climatic zones of *Dega, Woinadega* and *Kola* covering about 31%, 48% and 21% of the total area of the district, respectively. The annual temperature and rainfall vary between 10°C and 20°C and 200 and 2000 mm respectively, While, Regosols and Regosols-Arenosolsassociation, Lithosols, Rendzinas, Ranker, Cambisols, Luvisols, Nitosols, Acrisols and Vertic-Luvisols are the major soil types found in the district [57].

Livestock and crop-production are the main livelihood strategies of the rural household. Among the annual crops grown maize and sorghum are the dominant food crops which occupy the large proportion of cultivated land under annual crops and largely produced for household consumption. Barley, wheat and *teff* are also other food crops grown in the district. Coffee and *khat* are the main perennial crops which are the major sources of cash income for rural household. Out of cultivated area under perennial crops, 65% and 34% are covered by *khat* and coffee production respectively [15].

Table 1. *Estimated Area and proportion of Land uses in Bedeno District.*

S.N.	Land use	Area	
		Ha	% of total land area
1	Cultivated land	42958	44
2	Grazing land	7793	8
3	Forest and woodland	8085	8
4	Bush and shrubs	3994	4
5	Degraded land	21332	22
6	Other land	13248	14
Total		97410	100

Source: Bedeno *Woreda* Agriculture and Natural Resource Office Annual report, 2018.

2.2. Sampling Design and Data Collection Method

The district has 40 rural *K*ebeles, out of which 19 of them produce coffee [15]. Therefore, 11 *Kebeles* were purposefully selected out of the 19 based on the presence of shade based coffee production system and four of them randomly selected from which the target households were selected for this research. The *Kebele* Administrations in which the study was conducted were Tortora Kella, Eja Buna, Dertu Remmis and Hindeysa. Both quantitative and qualitative types of data were gathered. Primary data was collected between October to December 2019 through household survey and tree inventory using questionnaire and tree inventory form respectively from each selected smallholder farmers and coffee farm.

Stratified random sampling procedure was followed to select target HHs from each of the three main wealth categories to investigate how households in different wealth classes could affect tree species diversity of coffee farms. The Selected households were those whose coffee farms were used for vegetation data collection. The names of all HHs living in the *kebeles* were obtained from the *kebeles'* office and cross-checked with key informants for its inclusiveness and categorized into wealth classes by using *Kebele* council members and development agents based on local criteria set by key informants such as amount of cereal crops produced in quintal per year, number of cattle, total and perennial crop landholding size and standard of house.

The total sample size for sample household farmers was determined according to the sampling formula provided by Yamane [58]. Accordingly, the used formula for sample size determination with 95 % confidence level, degree of variability = 0.5 and level of precision 8.5 % (0.085) was:

$$n = \frac{N}{1+N(e^2)} \quad (1)$$

Total sampled size of households from the study KAs.

Where: - n = Sample size,

N= Population size and

e= the acceptable sampling error 90% confidence level

Sample size from each KA (n_1, n_2, $n_3 \ldots n_n$), was taken proportion to the total households (N_1, N_2, N_3) i.e.

$$n1 = \frac{N1*n}{N} \quad (2)$$

Where: - N_1= total household in KA 1,

n= total sampled household from the study KAs and

N = total households in the study KAs.

Therefore a total of 119 households were selected as 26 from rich, 42 from medium and 51 from poor wealth classes for this study (Table 2). Snow-ball sampling method was used for accessing key informants (KI) through contact information that provided by other informants to select individuals who have long experience and knowledge of cultivating coffee under shade tree species for the interview. Accordingly, a total of 32 key informants (KI) were selected, 8 from each four sampled *kebele* Admistration. They were used to provide information on preference, management and role of shade tree species of smallholder coffee farms. They were also used for identification of local names of shade tree. Therefore, in this study key informants are defined as those who have experienced and knowledgeable about cultivating coffee under canopy shade trees, changes in local conditions, households and who have lived a long time in an area.

The data of area of the land was, based on the land certificates issued to each farmer by Land administration and use office of the study district from 2018 to 2019.

Table 2. *Distribution of sample households by wealth classes in the district.*

SN	Sampled KAs	Number of sample households By wealth classes			
		Poor	Medium	Rich	Total
1	Tortora Kella	15	13	8	36
2	Eja Buna	12	9	6	27
3	Hindeysa	12	9	6	27
4	Dertu Remmis	12	11	6	29
Total		51	42	26	119

Source: Own computation from BWANRO data, 2018.

Tree inventories were carried out between October 28, 2019 to December 9, 2019, covering 119 smallholders' coffee farms that were randomly selected from the three main wealth categories (rich, medium and poor) of coffee-growers across the four study *Kebele* Administrations (Table 2). Due to lower density of trees within coffee farms, the whole farm was used as a sample plots (coffee plots) following Pinard et al. [47] in this study. Accordingly, the actual sizes of all selected coffee farms (n=119) were measured by using a GPS 60 (Geographic positioning system) device to make realistic comparisons on the diversity among the three households' wealth categories identified in the study area. Then after, all tree species were identified by their local names, for each tree with a height greater than or equal to two meters, the number of individuals of each species within the whole farm was counted, diameter at breast height (DBH) and height were measured and recorded in each sampled plot. Local name of all tree species found in the sampled coffee farms were recorded by the help of local community, including selected respondents and Key informants. Farmers' local names for tree species were documented and the identification of their scientific names of tree was carried out using books as a guideline [9].

2.3. Data Computation and Analysis

The species diversity and similarity were computed using diversity indices, namely Shannon diversity index, Shannon Evenness, Simpson's diversity index and Sorensen similarity index respectively. The Shannon index is an information statistic index, which means it assumes all species are represented in a sample and that they are randomly sampled [49]. While, the Simpson index is dominance index because it gives more weight to common or dominant species. In this case, a few rare species with only a few representatives will not affect the diversity [34, 37, 30] and hence, considered in this study. Accordingly, Shannon index and Evenness measures (E) which are commonly used models to incorporate both evenness and richness of relative abundance of species [37], were calculated. Therefore, Shannon diversity index (H) was calculated from the equation:

$$H' = -\sum_{i=1}^{s} \text{pilnpi} \quad (3)$$

Where: *H'*= is the Shannon-Weiner index/ Shannon Diversity index (H). A higher value of *H'* indicates high species diversity in the sample [37].

Pi = abundance of the i^{th} species expressed as proportion of the total abundance

lnpi= natural logarithm of *pi,*

S = the number of species i = 1, 2, 3…s

Evenness (Shannon equitability) index (E) was calculated to estimate the homogeneous distribution of tree species on coffee farms as follows:-

$$E = \frac{H'}{H\max} = \frac{H'}{\ln S} = \frac{\sum_{i=1}^{s} \text{pilnpi}}{\ln S} \quad (4)$$

Where:- *S* = the number of species

Pi = the abundance of the i^{th} species expressed as proportion of the total abundance. Equitability assumes a value between 0 and 1 with 1 being complete evenness [37].

Simpson's diversity index calculates a diversity score for a community. It takes into account the number of species present as well as the abundance of each species. The higher the score, the more diverse the community is considered to be [37]. Simpson's diversity index (D) was calculated by using the following formula as:

$$D = 1 - \sum pi^2 \quad (5)$$

Where: - *D*= is Simpson's diversity index and

Pi = is proportion of individuals found in the i^{th} species.

Community (*kebeles*) similarities were calculated to identify what they have in common interms of shade tree species. Sorensen similarity index (Ss) measures how the floristic compositions of different communities are similar. Therefore, tree species similarity analysis was complemented by calculating the floristic similarities among the study KAs using Sorensen's similarity index that is frequently referred to as the coefficient of community (CC) [38].

$$\text{Sorenson's Coefficient(CC)} = \frac{2C}{(S1+S2)} \quad (6)$$

Where: - C= is the number of species the two communities have in common,

S1 is the total number of species found in community 1 and

S2 is the total number of species found in community 2.

Sorenson's coefficient gives a value between 0 and 1, the closer the value is to 1, the more the communities have in common. Thus, complete community overlap is equal to 1; complete community dissimilarity is equal to 0.

The measured diameter at breast height (DBH) of the trees were categorized into nine (9) diameter classes as: 5 - 21, 21 - 37, 37 - 53, 53 - 69, 69 - 85, 85 - 101, 101 - 117, 117 - 133, and >133. Whereas the height of the trees were categorized into four as 2-5.9, 6-13.6, 13.7-22.9 and >22.9. Basal area (m^2) is the sum of the basal areas of all stems in the assessed area of land calculated as:

$$\text{Basal Area} = \frac{\pi(DBH)^2}{4} \quad (7)$$

Where:- BA = basal area (m^2);
π = 3.14 and
DBH = Diameter at breast height (m)

The relative importance of each tree species in the coffee farms was computed using the importance value index (IVI), which is the sum of relative density, relative frequency and relative dominance [30] after pooling the data from each plot for each species to evaluate the dominance level of a tree species in the coffee farm by using the formula of the syudy of Mueller et al. [43] as:

$$\text{IVI} = \text{Relative density} + \text{Relative frequency} + \text{Relative dominance} \quad (8)$$

Where: - IVI = Important Value Index;

$$\text{Relative frequency} = \frac{\text{Plot frequency}}{\text{Total Plot frequency}} \text{X100} \quad (9)$$

(i.e. it is calculated as the number of plots where a species is observed divided by the total number of survey plots.)

$$\text{Relative Dominance} = \frac{\text{Basal Area}}{\text{Total Basal Area}} \text{X100} \quad (10)$$

$$\text{Relative Density} = \frac{\text{Density}}{\text{Total Density}} \text{X100} \quad (11)$$

Both qualitative and quantitative of collected data were analyzed by the help of Microsoft excel and SPSS version 20 in this study. The analysis of tree species diversity parameters were carried out by using Microsoft excel and also checked by Statistical software PAST 3 (Paleontological Stastics). The results were subjected to one-way ANOVA Tukey's test to compare whether there was significant mean difference in tree species diversity among *Kebele* Administrations and wealth categories at *Kebele* level. Descriptive statistics were used to present the results.

3. Result and Discussion

3.1. Farmers Landholding and Coffee Size in the Study Area

According to the result of this study, a total landholding area of 119 respondents was 41.3 ha, ranging from 0.125 to 1.428 ha, with a mean farm size of 0.347 ha. Majority of respondents (55.5%) have land holding size ranged between 0.125 - 0.275 ha, while, 25.2%, 7.6% and 4.2% of the respondents have between 0.275 - 0.425 ha, 0.425 - 0.575 ha and 0.875 - 1.025 ha respectively, while, the lefst 0.575 - 0.725 ha, 0.725 - 0.875 ha and more than 1.025 ha landholding classes comprises 2.5% of the total interviewed households (Figure 2). Therefore most of the farmers who were more likely to practice coffee agroforestry had smaller hectares of land size. Inline with this study [27] reported that most of the households who practices traditional agroforestry in West Hararghe Zone, Ethiopia had land holding size of 0.25 - 0.5 ha. However, the far higher average land size was reported as compared to the result of this study with a value of 1.25 in Southern Ethiopia [8] and 0.6 ha Central Kenya [47] and 1.6 ha in Eastern Kenya [44].

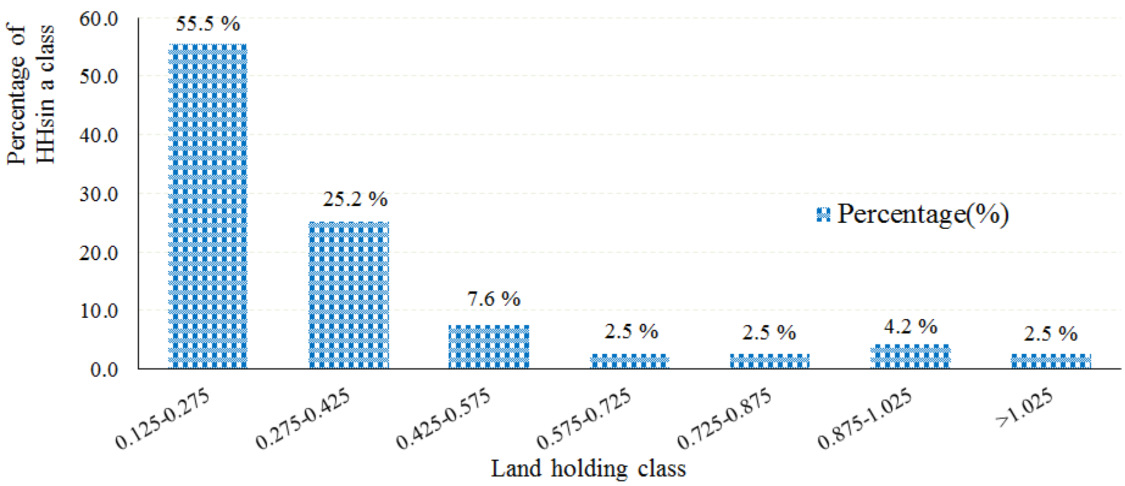

Figure 2. *Distribution of respondents in a landholding classes.*

The survey of all selected coffee farms covered a total area of 14 ha, with the average value of 0.118 ha which ranged from 0.04 to 0.326ha. On average coffee farm covered 34% of farmers' total landholding. Accordingly, about (52.1%) of respondents were shared between 30 to 50% of their total land holding, whereas, 38.7% and (9.2%) of the interviewed respondents shared between the range of 10 - 30 and more than fifty percent of their total land for shaded coffee production system (Figure 3). The result of this study relatively similar with the finding of Pinard et al. [47], who indicated the mean value of farmers' farm size of 0.16 ha and average coffee farm coverage of 33% out of farmers' land holding in Central Kenya as compared to the result of this study, which is relatively comparable with the result of this study.

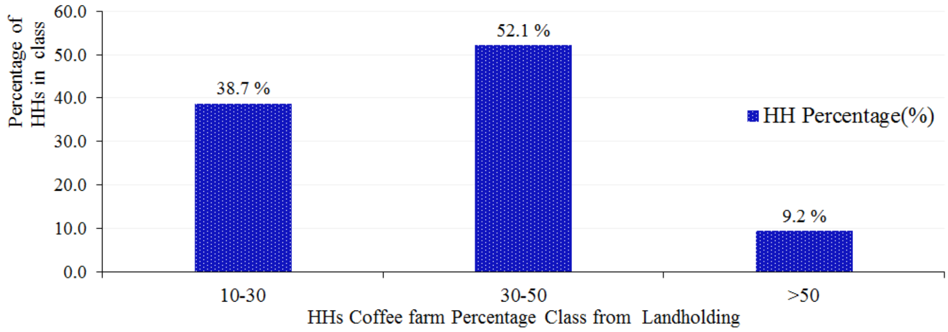

Figure 3. *HHs coffee percentage from their total landholding.*

3.2. Tree Species Diversity and Frequency in Smallholders' Coffee Farms

3.2.1. Tree Species Richness and Abundance

This study revealed that considerable number of tree species are being managed and conserved in coffee farms. Accordingly, a total of 1267 trees belonging to 53 species and 28 families (Appendix 1) were encountered in smallholder coffee farms with high variability of one to 16 species and two to 35 individuals per farm. The 10 most abundant tree species encountered were accounted for about 73.8% of the total tree counts, while the top five species were accounted for 56.5% of all the trees counted. These top five species were *Cordia africana, Anona senegalensis, Croton macrostachyus, Acacia albida* and *Mangifera indica* (Figure 4). Nineteen percent of the species encountered were represented by single individual tree. Furthermore, Family *Fabaceae* was the largest family with 18.9% of the recorded species, while, Moraceae was the second largest with 9.4% species followed by, Anacardiaceae and Rutaceae 7.5%, Boraginaceae and Myrtaceae 5.7%, as well as Annonaceae and Cupressaceae 3.8% respectively. The left 21 families (Apocynaceae, Asteraceae, Bignoniaceae, Casuarinaceae, Combretaceae, Euphorbiaceae, Flacourtiaceae, Lauraceae, Loganiaceae, Meliaceae, Moringaceae, Oleaceae, Portulacaceae, Proteaceae, Rhamnaceae, Rosaceae, Rubiaceae, Sapotaceae, Tiliaceae and Ulmaceae) were represented by a single (1.9%) species (Figure 5).

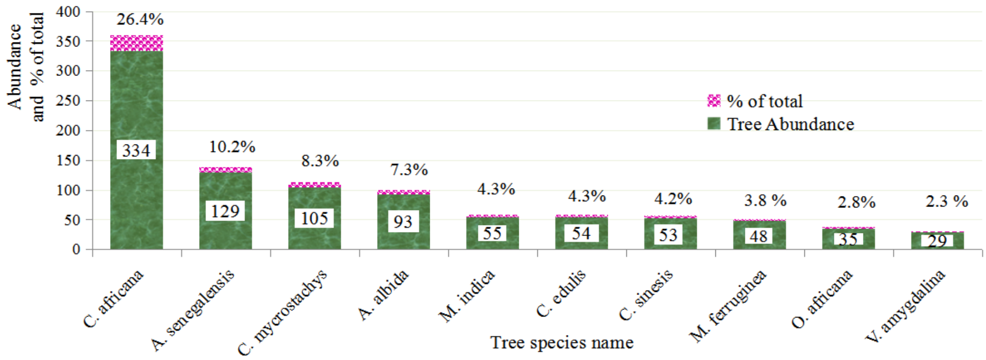

Figure 4. *Top ten abundant tree species in the coffe farms of the study area.*

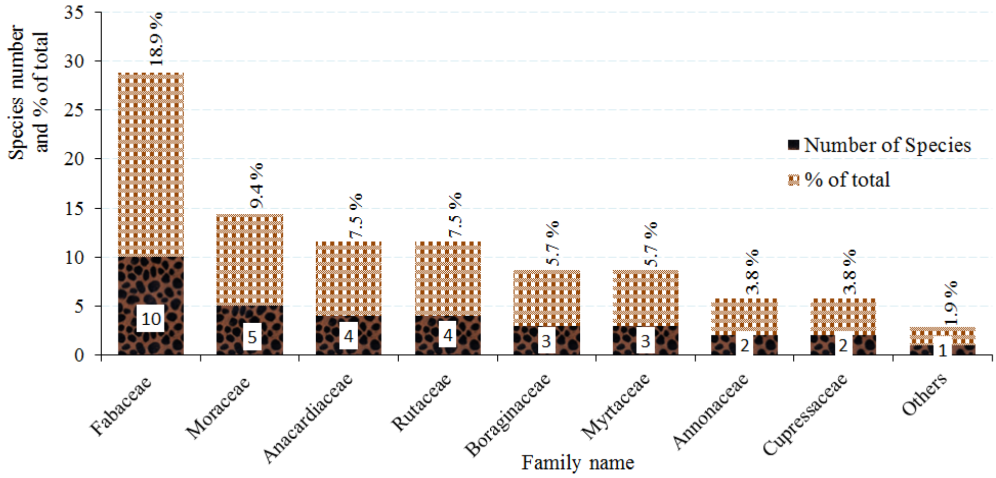

Figure 5. *The family of tree species in the study area.*

Based on their origin most of the total 53 recoded tree species (69.8%) were indigenous out of which two were endemic to Ethiopia, while the left 30.2% were exotic tree species (Appendix 1). The abundance of common fruit trees in the coffee farms were shown to be 24.5% of all recorded species, representing 30.6% of the total tree counts. Inconsistent with this, the study result of Samson et al. [48], reported the higher number of indigenous 65% trees species than exotic (35%) out of the recorded 63 species in the coffee farms at central Uganda, which is comparable with the result the current study area. Likewise, the result of this study also relatively similar with the study result of Ebisa wt al. [18], who reported a total of 53 tree species with the higher indigenous tree species 60.4% in coffee farms at Mana-sibu district of western Oromia, Ethiopia. Similarly, Ambinakudige wt al. [5] found the presence of 47 tree species in coffee farms at Western Ghats of India which is nearly similar with current study result.

The number of species recorded in the current study area was low when compared to earlier studies conducted in coffee farms of other regions, although many of the species encountered were not common in the coffee fields. For example, Lopez wt al. [36] reported 107 tree species used as coffee shade in Veracruz, Mexico. On the other hand, the encountered number species in this study was high as compared to other earlier study conducted by Mohammed [40], who have been recorded a total of 29 trees used in the coffee agroforestry systems of Jimma Zone, South Western Ethiopia, Yitebitu [59] mentioned 34 species in coffee farm in Gedeo Zone of Southern Ethiopia, [21] who have been recorded a total of 29 tree species used in the coffee farm in Western Wellega Zone, Ethiopia, [19], recorded 39 tree species in the coffee farm in Manasibu districts of western Oromia, Ethiopia and [20] who reported 36 tree species used in the coffee farm in West Lampung of Indonesia. Additionally, [46] recorded 43 total number of tree species in coffee farms Eastern Uganda which is lower than the result of this study.

On average, the overall richness and abundance varies from 5.11 to 5.78 and 9.44 to 11.63 respectively across the study *Kebeles*. Furthermore, the results of this study shows significant difference in the mean value of richness and abundance of tree species (P < 0.05) among the three wealth categories across the four study *Kebeles*, which indicated the richness and abundance per household were significantly affected by wealth status, with a higher value on coffee farms of rich households than medium and poor households. For example, the highest richness was recorded on the farm of rich household with the value of (11.5±3.6), while, the lowest was recorded on the farm of poor household (3±1.04) both in Dertu Remmis *kebele.* Likewise, the highest mean abundance was recorded on the farm of rich household with the value of (22.83±7.36) in Eja Buna *kebele* and the lowest was recorded on the farm of poor household (4.83±1.03) in Hindeysa *kebele* (Table 3).

The result of the current study area was similar with the study of [21] from at wesstern Wellega, Ethiopia. Similarly, different earlier related study in other parts of Ethiopia reported that, the richness and abundance significantly influenced by wealth categories of respondent farmers [44, 36].

Table 3. *Richness and Abundance (mean±Std) of tree species belonging to three wealth categories in the study site.*

Kebeles name	W/ Classes	No of plot	Species Richness (S)	Abundance
Tortora Kella	Rich	8	10.13±3.44[a]	19.38±5.1 [a]
	Medium	13	5.62±1.33 [b]	12.15±3.76[b]
	Poor	15	3.6±1.12 [c]	5.93±1.79 [c]
	Total	36	5.78±3.14	11.17±6.23
Eja Buna	Rich	6	10.67±3.08[a]	22.83±7.36 [a]
	Medium	9	5.33±1.22 [b]	11.33±4.03 [b]
	Poor	12	3.17±1.11 [c]	6.25±2.56 [c]
	Total	27	5.56±339	11.63±7.78
Dertu Remmis	Rich	6	11.5±3.6 [a]	20±5.66 [a]
	Medium	11	5.36±2.25[b]	9.73±4.15 [b]
	Poor	12	3±1.04 [c]	5.75±2.09 [c]
	Total	29	5.66±3.86	10.21±6.54
Hindeysa	Rich	6	8.33±2.58 [a]	17.5±7.75 [a]
	Medium	9	5.44±1.51 [b]	10.22±2.17 [b]
	Poor	12	3.25±0.75 [c]	4.83±1.03 [c]
	Total	27	5.11±2.50	9.44±5.97

Different letters following vertical mean values indicate significant difference (P<0.05) between wealth categories with in study Kebeles.

3.2.2. Tree Species Diversity Indices

Shannon, Evenness and Simpson diversity indices were calculated for the three households' wealth classes at each four study *Kebeles* for the comparison of the mean values of diversity indices. Therefore, there was significant difference in the mean value of Shannon diversity index (P < 0.05) among the three wealth categories across all study *Kebeles,* while, Simpson index shows significance mean difference (P < 0.05) only among poor and the two (rich and medium) wealth classes in all study *Kebeles* (Table 4). From all wealth categories, the highest and the lowest Shannon and Simpson diversity index was recorded with the value of (H'= 2.7 and 1-D = 0.92) for rich and both zero (0) for poor wealth class in Dertu Remmis *Kebele*. Likewise, the study result of Ewunetu et al. [21], indicated that the rich wealth groups had significantly higher Shannon and Simpson diversity indices in the coffee farms at western Wellega Zone of Western Ethiopia. On the other hand, an Evenness diversity index does not show significant mean difference (P > 0.05) among the three wealth categories at the current study site (Table 4). In support of the finding of this study, Ewunetu et al. [21] reported that, Shannon diversity depend on species richness. In addition to this, Tesfaye [54] reported that the higher Shannon diversity index were associated with increase in species richness in their study of diversity in Home garden agroforestry systems of Southern Ethiopia.

Table 4. *Mean value of Tree Diversity indices (mean±Std) belonging to three wealth categories in the coffee farm of study area.*

Kebeles' Name	W/Classes	No of plot	Shannon index (H')	Evenness (E)	Simpson index (D)
Tortora Kella	Rich	8	2.16±0.28 [a]	0.95±0.02 [a]	0.87±0.03 [a]
	Medium	13	1.53±0.28 [b]	0.9±0.07 [a]	0.74±0.09 [a]
	Poor	15	1.09±0.43 [c]	0.83±0.26 [a]	0.59±0.21 [b]
	Total	36	1.49±0.54	0.88±0.17	0.71±0.18
Eja Buna	Rich	6	2.17±0.29 [a]	0.93±0.03 [a]	0.87±0.04 [a]
	Medium	9	1.53±0.26 [b]	0.92±0.05 [a]	0.75±0.07 [a]
	Poor	12	1.01±0.34 [c]	0.92±0.05 [a]	0.59±0.13 [b]
	Total	27	1.44±0.54	0.92±0.05	0.71±0.15
Dertu Remmis	Rich	6	2.29±0.35 [a]	0.95±0.03 [a]	0.88±0.04 [a]
	Medium	11	1.48±0.43 [b]	0.93±0.04 [a]	0.73±0.12 [a]
	Poor	12	0.92±0.44 [c]	0.80±0.28 [a]	0.53±0.23 [b]
	Total	29	1.42±0.66	0.88±0.19	0.68±0.21
Hindeysa	Rich	6	1.92±0.36 [a]	0.92±0.04 [a]	0.82±0.07 [a]
	Medium	9	1.5±0.36 [b]	0.90 ±0.09 [a]	0.73±0.13 [a]
	Poor	12	1.1±0.24 [c]	0.95±0.05 [a]	0.64±0.08 [b]
	Total	27	1.42±0.44	0.92±0.07	0.71±0.12

Different letters following vertical mean values indicate significant difference (P<0.05) between sites.

The results of the current study indicated a high species overlap between the coffee farms of four study *kebeles*. The four study *Kebeles* shared 13 species in common, while 35.8% species were found exclusively in a single *Kebele* (Hindeysa (11.3%), Eja Buna and Tortora Kella each (9.4%) and Dertu Remmis (5.7%)). The remaining 18.9% and 20.8% species occurred in three (Tortora Kella, Eja Buna and Dertu Remmis (9.4%); Tortora Kella, Dertu Remmis and Hindeysa (3.8%), Tortora Kella, Eja Buna and Hindeysa (3.8%) and Eja Buna, Dertu Remmis and Hindeysa (1.9%)) and the two (Tortora and Hindeysa (7.5%); Tortora Kella and Dertu Remmis; Tortora Kella and Eja Buna each (1.9%) and Eja Buna and Dertu Remmis and (9.4%)) study kebeles respectively.

Therefore, Sorensen's similarity index ranged from 0.53 to 0.77 between sites (KAs) indicating high tree species overlap. The highest similarity (0.77) in species composition was observed between Eja Buna and Dertu Remmis KAs, which were relatively farther apart than between Eja Buna and Hindeysa (0.53) those were relatively closer. The results suggest that distance between the *K*As did not influence the variation in species composition among the KAs because the highest similarity was observed from both those are apart and also the nearest sites. For example, Eja Buna and Dertu Remmis KAs with the highest similarity (0.77) in species composition were the nearest *kebeles* to each other. Similarly, Tortora Kella and Hindeysa KAs with the second highest similarity (0.69) were also the nearest *kebeles* to each other. On the other hand, Dertu Remmis and Hindeysa whith the second lowest similarity (0.55) were also the nearest *Kebeles* to each other. Whereas, Tortora Kella and Dertu Remmis with the third hieghest similarity (0.67) and Eja Buna and Hindeysa with the lowest similarity were the far apart *K*As from each other.

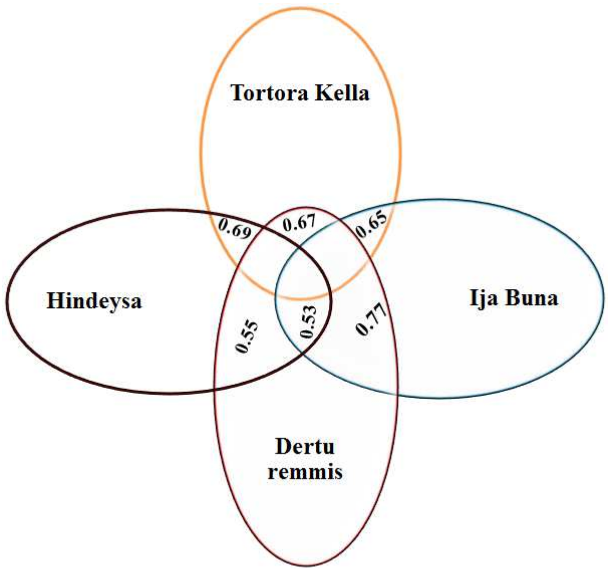

Figure 6. *The Sorenson's Similarity index among the four study Kebeles in the study area.*

3.2.3. Tree Species Frequency Distribution

The overall frequency of occurrence of shade tree species ranged from 0.84 to 91.6% of the plot surveyed. The seven most frequent tree species in the coffee farm of the study area were *C. africana* (91.6%), *A. senegalensis* (65.6%), *C. macrostachyus* (45.4%), *A. albida* (38.7%), *C. edulis* (27.8%), *M. indica* (26.9%) and *M. ferruginea* (22.7%) (Figure 7), while, 12 tree species (*A. seyal, A. schimperi, A. muricata,* Mango spp (grafted Apple mango*), C. equisetifolia, Celtis africana, J. mimosifolia, M. kummel, N. congesta, Portulaca Sp, R. vulgaris* and *M. alba* were the lowest tree species selected for only one coffee farm with the frequency of 0.84%. Among seven most frequently encountered tree species, three were fruit trees (*Annona senegalensis, Mangifera indica and Casimiroa edulis)* (Figure 7). Most of tree species found in the studied coffee farm of the current study area were frequently cited in other earlier related studies. For example, *A. gummifera*, *A. abyssinica*, *C. sinesis*, *C. africana, C. macrostachyus, E. camaldulensis*, *F. sycomorus*, *F. thonningii*, *F. sur*, *F. vasta*, *M. indica*, *M. ferruginea*, *O. africana*, *P. guajava*, *S. guineense* and *V. amygdalina* were reported in the coffee farms at Western Wellega, Ethiopia [21].

The result of this study is also similar with what was reported from coffee agroforestry systems in the Hararghe highlands of eastern Ethiopia and identified native coffee shade trees, such as: *A. gummifera, A. abyssinica, M. ferruginea, F. sur, Ficus vasta* and *C. africana* [39]. Likewise, *P. americana, C. africana, M. indica, M. ferruginea, F. vasta* and *P. guajava* were reported in South Gonder Zone, North West Ethiopia [1], whereas, *A. nilotica, A. gummifera, C. aurantifolia, C. sinesis, C. africana, C. macrostachyus, C. lusitanica, A. sennegalensis, F. vasta, J. procera, M. indica, M. ferruginea, O. africana, P. americana, P. guajava* and *V. amygdalina* were reported in the traditional Agroforestry of West Hararghe Zone, Oromia National Region State, Ethiopia [27]. Moreover, the finding of the current study was also relatively comperable with the reported study result of Samson et al. [48] and Anteneh et al. [6], who reported, *C. africana and* fruit trees as the most dominant tree species that mainly planted and/or retained in the coffee farms for income, nutrition and as a buffer for the ever present vicissitudes that face the coffee sector in Uganda and *C. africana, M. ferruginea, A. abyssinica, Albizia sp.* and *E. abyssinica* as suitable shade tree species for coffee production as most of them have wider canopies and feathery leaves to provide coffee plant beneath with moderate light regime and replenish organic matter through decomposition litter fall respectively.

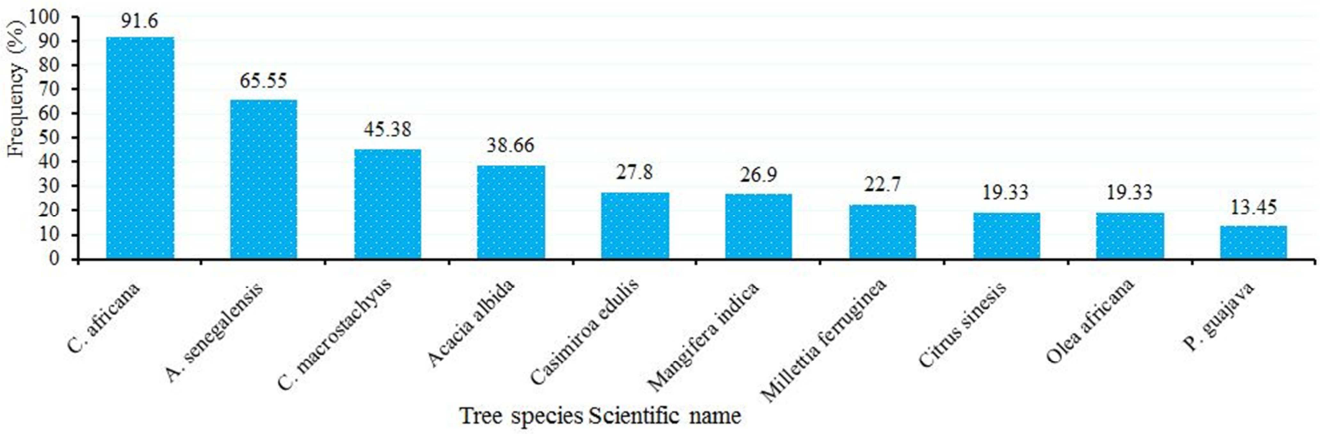

Figure 7. *Frequency of top ten tree species in smallholder coffee farms of the study area.*

3.2.4. Distribution of Diameter at Breast Height (1.37 m)

The result of this study shows the higher tree abundance at the lower DBH. Accordingly, most of the trees in the coffee farms had DBH between 5 - 21 and 21 - 37 class, which accounted for 37% and 35%, followed by 37 - 53 (17%) and 53 - 69 (5%); 69 – 85 (2.5%); 85 – 101 (1%) of all individual trees in the surveyed coffee farms respectively. The remaining each three classes (101 - 117, 117 - 133 and >133) contributed for less than one percent of the total tree count (Figure 8). Therefore, the total number of trees in each DBH class relatively decreased with an increasing tree diameter classes and the dominance of small trees may be due to the continuity of planting and managing trees. The higher DBH class (≥80) were dominated by only four species (*C. africana* (38%), *A. albida* (18%), *F. sycomorus* (12%), *E. capensis* (8%)) covering 76% out of the total encountered 50 individual tree in a class, while, the lower (5 – 21) DBH class was dominated by seven species (*C. africana* (20%)*, A. senegalensis* (12%)*, C. sinesis* (8%)*, C. edulis* (7%) *and C. macrostachyus* (6.5%)), covering 54% of the total encountered 474 individuals in the DBH class, while the second lower class (21 – 37) also dominated by only six species (*C. africana* (26.5%)*, A. senegalensis* (14.1%)*, C. macrostachyus* (7.7%), *A. albida* (4.8%)*, M. indica and O. africana* (3.6%)), covering (56.7%) of the total 441 individuals with in a class. The result of the current study is similar with the finding of Lalisa et al. [35] from central highlands of Ethiopia, who reported, the dominance small trees.

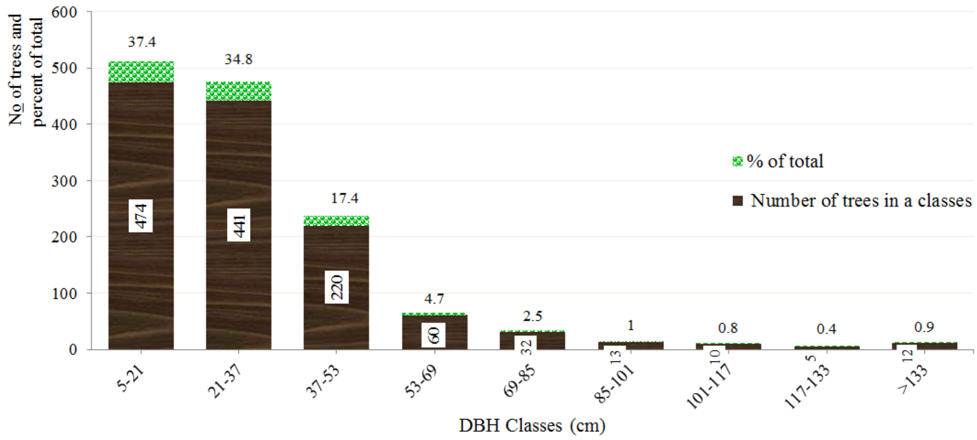

Figure 8. *Distribution of total number trees with their percentage in DBH classes.*

3.2.5. Height Class Distribution

Concerning the height class distribution, most of the trees in the coffee farms 500 (40%) had the height between 2 to 5.9 m followed by 6-13.6, 13.7-22.9 and more than 22.9 m height class, which respectively accounted for 366 (29%), 246 (19%) and 155 (12%) of all the trees in the farms (Figure 9). Therefore, the total number of individuals in each successive height class was decreasing from the first lower height class to the highest class, indicating the higher tree abundance at the lower height classes.

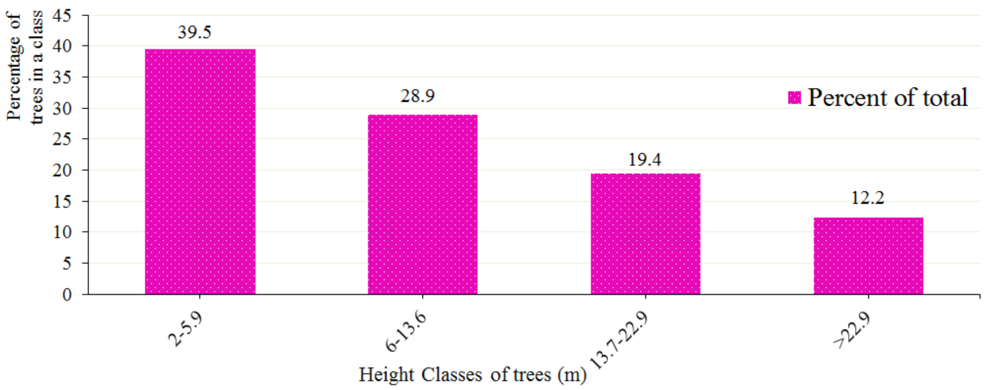

Figure 9. *The height class distribution of individual trees in the study area (percentage).*

3.2.6. Basal Area (BA in m²/ha)

The total average basal area (BA) of tree species was 12.8 m²/ha with a maximum and minimum value of 3.5 and 0.0002 m²/ha respectively. The maximum total basal area (3.5 m²/ha) per species was recorded with *C. africana* with the relative basal area of 27.1%, followed by *A. albida* (2.2 m²/ha, 17. 2%) and *F. sycomorus* (1.5 m²/ha, 12%) (Table 5). On the other hand, the smallest basal area (<1 m²/ha), was observed with about fourty eight species. Only five species had a basal area between the range of 1 and 3.5 m²/ha.

Table 5. *Top ten tree species with highest Basal area (m²/ha) in the study area.*

Tree species Name	Mean DBH per Species (cm)	Mean DBH per Species (m)	BA (m²)	BA m²/ha by study *Kebele*						Relative BA (%)
				Tortora Kella	Eja Buna	Dertu Remmis	Hindeysa	Total	Average	
C. africana	146.01	1.46	46.55	1.69	4.61	5.73	1.91	14	3.5	27.1
Acacia albida	168.09	1.68	28.92	0.44	2.75	5.65	0.02	8.9	2.2	17.2
F. sycomorus	451.7	4.52	19.67	0.1	3.55	1.76	0.73	6.2	1.5	12
E. capensis	154.97	1.55	11.59		0.4	3.22	0.02	3.6	1	7.1
C. macrostachyus	122.27	1.22	9.75	0.69	0.88	0.88	0.31	2.8	1	5.4
A. senegalensis	85.03	0.85	6.01	0.42	0.12	0.36	0.84	1.7	0.4	3.4
M. ferruginea	134.6	1.35	5.74	0.44	0.36	0.53	0.29	1.6	0.4	3.2
T. brownie	126.73	1.27	4.27	0.24	0.11	0.87		1.2	0.3	2.4
J. procera	60.13	0.6	3.74	0.032			1.2	1.2	0.3	2.4
Ficus vasta	249.14	2.49	3.91	0.18	0.31		0.7	1.2	0.3	2.3

Source: From survey of 2019.

3.2.7. Tree Species Importance Value Index (IVI)

In the coffee farms of the current study, *C. africana* (23.2%), *Acacia albida* (10.5%), *A. senegalensis* (8.5%), *C. macrostachyus* (7. 2%), *F. sycomorus* (4.9%), *M. indica* and *Millettia ferruginea* (3.7%) and *C. edulis* and *Ekebergia capensis* (3.6%) were found to be the nine most important species based on their IVI (Table 6). Therefore, the result of importance value index shows the dominance of only few tree species in the coffee farms. The high IVI value of these tree species seems to relate to the farmers' conscious management of trees for its various benefits. This has an implication on the conservation efforts need to be made for the less beneficial and rare species. The finding of the current study was thus in line with previous study of Negawo et al. [46], who reported the dominance contribution of about 77 % of IVI of tree and shrub species by 12 out of a total 50 species in coffee farms in Eastern Uganda. Similarly, Samson et al. [48] reported ten important species out of which five were most important species from 63 recorded species in coffee farms of central Uganda. Moreover, it was reported that, the most important tree species are those most common and abundantly planted/retained in coffee agroforestry system [54, 42]. The highest overall Importance Value Index of *Cordia africana, Acacia albida and Ficus sycomorus* was recorded due to their highest basal area which made these species having a larger value of relative dominance with 27.1, 17.2 and 11.97% respectively. In addition to this, the larger value of relative frequency and relative density of *Cordia africana* (16.5 and 26%), *Anona senegalensis* (11.8% and 10.2%), *Croton macrostachyus* (8.2 and 8%) *and Mangifera indica* (4.9% and 4.2%) respectively contributed to the highest importance values of the species. Similarly, Aklilu et al. [4] and Buchura et al. [14] reported that IVI value is determined by density, frequency and basal area. Likewise, Simon et al. [50] also revealed that species with the greatest importance values were the most dominant of particular vegetation which is compare able with the result of this study.

Table 6. *Top ten tree species with the highest IVI in the study area (n= 119).*

Tree Species name	Relative Frequency (%)	Relative Dominance (%)	Relative Density (%)	IVI (%)
Cordia Africana	16.54	27.1	26.03	23.2
Acacia albida	6.98	17.2	7.46	10.5
Annona senegalensis	11.84	3.4	10.2	8.5
Croton macrostachyus	8.19	5.4	7.96	7.2
Ficus sycomorus	1.82	11.97	1.05	4.9
Millettia ferruginea	4.1	3.2	3.79	3.7
Mangifera indica	4.86	2.1	4.17	3.7
Casimiroa edulis	5.01	1.3	4.42	3.6
Ekebergia capensis	1.97	7.1	1.65	3.6
Citrus sinesis	3.49	0.97	4.45	3.0

Source: From survey result of (2019).

4. Conclusion and Recommendation

Smallholder coffee farms of the current study area have the potential to maintain tree species diversity, being dominated by indigenous multi-purpose trees. Wealth status of the respondent farmers influenced the diversity of tree species, in where, rich coffee growers owned more diverse species than the medium and poor wealth classes. The analysis of the IVI shows that only few trees species dominate on farms, including, *Cordia africana, Acacia albida, Annona senegalensis and Croton macrostachyus*. Therefore, Traditional shade based coffee production system should be encouraged for tree species diversity conservation in smallholder coffee farms.

Acknowledgements

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Appendix

Table 7. *List of tree species with their local, Scientific and family names and origin in the study site. (A. O. = Afan Oromo).*

Species Scientific Name	Family name	Local name (A. O.)	Origin	Endemicity
Acacia abyssinica	Fabaceae	Sarkama	I	
Acacia albida	Fabaceae	Gerbi	I	
Acacia etbaica Schweinf.	Fabaceae	Doddoti	I	
Acacia nilotica	Fabaceae	Lafto	I	
Acacia seyal	Fabaceae	Wachu	I	
Acokanthera schimperi	Apocynaceae	Qararu	I	
Albizia gummifera	Fabaceae	Hambabessa	I	
Annona muricata	Annonaceae	Ambashok	E	
Annona senegalensis	Annonaceae	Gista	I	

Species Scientific Name	Family name	Local name (A. O.)	Origin	Endemicity
Casimiroa edulis	Rutaceae	Ambadada	E	
Casuarina equisetifolia	Casuarinaceae	Shewshawe	E	
Celtis africana Burm. F	Ulmaceae	Meta koma	I	
Citrus aurantifolia	Rutaceae	Tuto	E	
Citrus reticulate	Rutaceae	Mandariina	E	
Citrus sinesis L.	Rutaceae	Burtukana	E	
Cordia africana Lam	Boraginaceae	Waddessa	I	
Cordia monoica Rucb.	Boraginaceae	Menderro	I	
Croton macrostachyus Del.	Euphorbiaceae	Bekkennisa	I	
Cupressus lusitanica	Cupressaceae	G/feranji	E	
Ehretia cymosa	Boraginaceae	Ulaagaa	I	
Ekebergia capensis (E. rueppeliana)	Meliaceae	Sombo	I	
Erythrina abyssinica	Fabaceae	Wolensu	I	
Erythrina brucei	Fabaceae	Walensu	I	Endemic
Eucalyptus camaldulensis Dehnh.	Myrtaceae	Barg/ dimaa	E	
Ficus sur Forssk.	Moraceae	Habru	I	
Ficus sycomorus L.	Moraceae	Odaa	I	
Ficus thonningii Blume	Morace*ae*	Dembi	I	
Ficus vasta Forssk	Moraceae	Qilxuu	I	
Gardenia volkensii	Rubiaceae-	Gambello	I	
Grevillea robusta	Proteaceae	Gravilea	E	
Grewia bicolor	Tiliaceae	Haroorysa	I	
Jacaranda mimosifolia	Bignoniaceae	Muk/ kawe	E	
Juniperus procera	Cupressaceae	G/habasha	I	
Mangifera indica L.	Anacardiaceae	Mango	E	
Mango Spss	Anacardiaceae	Apple mango	E	
Millettia ferruginea (Hochst.) Baker	Fabaceae	Birbira	I	Endemic
Mimusops kummel	Sapotaceae	Oladi	I	
Moringa stenopetal (Baker f.) Cufod.	Moringaceae	Shifera	I	
Morus alba	Moraceae	Enjorri	E	
Nuxia congesta R. Br. ex Fresen.	Loganiaceae	Machalo	I	
Olea africana Mill.	Oleaceae	Ejersa	I	
Oncoba spinose	Flacourtiaceae	Jilbo	I	
Persea Americana	Lauraceae	Avocado	E	
Portulaca Sp.	Portulacaceae	Jibri	I	
Prunus persica	Rosaceae	Kuki	E	
Psidium guajava L.	Myrtaceae	Zeyituna	E	
Rhus glutinosa	Anacardiaceae	Urruba	I	
Rhus vulgaris	Anacardiaceae	Tatessa	I	
Sizygium guineense	Myrtaceae	Baddeessa	I	
Tamarindus indica	Fabaceae	Roka	I	
Terminalia brownie	Combretaceae	Birreensa	I	
Vernonia amygdalina Del.	Asteraceae	Ebicha	I	
Ziziphus mauritiana	Rhamnaceae	Kurkura	I	

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