Tree Species Diversity, Preference and Management in Smallholder Coffee Farms of Western Wellega, Ethiopia

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Abstract
Shade coffee agroforestry systems have the potential to support biodiversity. Yet assets and limits of their contribution are insufficiently documented. A sound understanding of farmer strategies in the management of coffee tree biodiversity is also critical to landscape approaches for biodiversity conservation and livelihood improvement. The objective of this study was to assess tree species diversity, preference and management practice in smallholder coffee farms of Babo Gembel, District, Western Wellega Ethiopia. Three Kebeles purposively and two villages randomly from each site were selected. Tree species diversity inventories were studied in a random sample of 54 coffee farms. A total of 29 tree species representing 15 families of which twenty four (83%) of these species were indigenous and the remaining five (17%) exotic species were recorded in coffee farms. There was significant difference ($p<0.05$) between kebeles in terms of species diversity. Wealth status of the household influenced the tree species diversity of coffee farms. The rich class was found to own more diversified tree species. Farmers grow indigenous multipurpose trees on their farms based on perceived ecological and economic usefulness of the species. Transplanting seedling of preferred shade tree species from natural forest in to coffee farms were the most common traditional practice. Pruning, thinning, weeding, hoeing, and watering were the most common management practice for the coffee farm system. Few weeks after onset of the main rainy season, most herbaceous vegetation, emerge and compete with coffee and should be cleared. In general, traditional coffee production system is an important land use system in conserving native tree species and should therefore be encouraged.
Keywords: Coffee farm, preference, structure, tree diversity, Western Oromia Ethiopia.

1. INTRODUCTION

As tropical deforestation and fragmentation continues, agricultural production landscapes may necessarily play important roles in conserving biodiversity [1]. More than 90% of tropical biodiversity is found in human-modified landscapes, outside protected areas [2].

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 [3]. For instance, [4] found shade grown coffee (an agroforestry system) to have higher levels of biodiversity in comparison to sun coffee. Other studies also shows existence of diverse tree species in shade coffee agroforestrysystem. For example, [5] reported the presence of 39 species in coffee farms in the Western Ghats of India. Likewise, [6] has also reported 36 tree species in the coffee farms of Manasibu districts, western Oromia.

In addition to biodiversity conservation shade trees provide products such as fruits, firewood and local construction material. Shaded coffee systems also provide a range of supportive, regulatory, and provisioning ecosystem services to smallholder coffee farmers [7] .Over time coffee shade system can conserve soil by increasing soil fertility and reducing nutrient leaching [8].

Many farmers understand the habitat and growth requirements of many species, seasonal yields, compatibility with other species, and relate site characteristics of the land they farm [9]. Likewise coffee farm managers are typically small holder farmers who derive most of their income from coffee as it is the only cash-crop for many of them [10]. For instance, Thinning the tree canopy to reduce shade in an effort to increase coffee production in Latin American coffee producing regions [11] and some Ethiopian coffee agroecosystems [12,13].

Cultivating coffee under varieties of shade tree species is common practice in smallholder coffee farms in the study area (Babo Gembel district). The tree component of the farms usually comprises a variety of tree species that were either planted by farmers or established through natural regeneration. It seems that the smallholder coffee farms of this area have also a considerable contribution towards tree diversity conservation similar to other coffee producing regions of the world. To realize the conservation role of coffee farming system and ensure its sustainability, however, deeper knowledge on the level of tree diversity preference and management that exists in the coffee farms has significant importance. Therefore, the objective of this study is to assess tree species diversity, and management in smallholder coffee farms of Babo Gembel district, western Oromia Ethiopia

1. MATERIALS AND METHODS

1.1. Description of the study area

The study was conducted in Babo Gembel district, west Wellega, Oromia regional state, Ethiopia(09° 17’- 09° 37’ N Latitude and 34° 55’-35° 15’ E Longitude (Figure 1). The topography of the area is generally characterized by flat gentle slope to undulating terrain, with an altitudinal range of 1419 - 1976 m.a.s.l. According to [14]. the major soil types found in the district are Fluvisols, Regosols and Vertisols. The district experiences a mean annual minimum temperature of 16^{o}C and annual maximum temperature of slightly above 27 ^{o}C with the annual rainfall ranges between 1800 – 2000 mm, with a long period of summer rain from May to September. Agriculture is the principal source of livelihood for rural population in the district. Cultivating coffee under varieties of shade tree species is common practice in smallholder coffee farms of Babo Gembel, District, Wes tern Oromia [14]. The kebeles administration (KAs) in which the study was conducted were Haromariam, Shumeltoke and Boni. Relative Coffee farm age and level of household dependency on coffee production was decreasing from Haromariam to Boni KAs respectively. The selected KAs found in the same agro ecological zone.

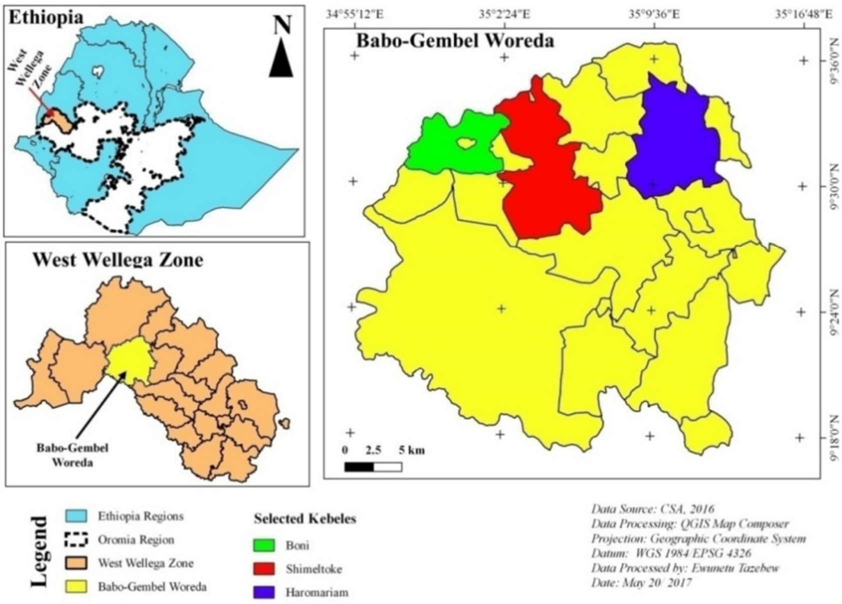

Figure 1: Location map of the study area

1.2. Sampling design and data collection

From the district, three kebeles administrations (KA) were selected based on the existence and extensive practice of shade coffee agroforestry six villages (two from each kebele) namely Zoni-Haromariam and kute_korma from Haromariam KA, Lolchisa and Sedeqa from Boni KA and Melkayida and Qiltu-babo from Shumolteke (site) were selected. Key informants (KI) were used to stratify villagers by wealth categories, and to provide information on management and role of shade tree species of smallholder coffee farms. They were also used for identification of local names of tree species in smallholder coffee farms. The selection of key informants at each village was done by adapting snowball method. Key informants (KI) in this study are defined as persons who are knowledgeable about shade tree management practices, coffee production and changes in local conditions, village households and who have continuously lived for a long period of time at least more than 30 years in the villages. The selection of the key informants was done by the snowball method. To select individual farmers who could identify key informants, village tour was made with kebele council members and development agents. During the village tour, five individual farmers were randomly asked to give the names of seven key informants. At each village, out of 42 key informants suggested, five top ranking were selected to categorize HHs into wealth classes.

The name of all HHs living in the villages was obtained from the kebele’s office and cross-checked with key informants at each village for its inclusiveness. Wealth ranking of individual HHs was carried out by adapting wealth-ranking technique of [15]. Primarily, the criteria for differentiating HHs into different wealth classes were set by key informants. Then, HHs living in the villages were categorized into three wealth classes of rich, medium and poor according to the set criteria (appendix 1) The purpose of wealth ranking in the study was to investigate how HHs in different wealth classes could affect shade tree diversity of coffee farms. A total of thirty key informants, five for each village, were involved in the classification of HHs.

After the KIs arranged then households were selected from each village of three PAs using stratified proportional random sampling following [16]. sample size determination methods. $n=N/1+N*e^2$ total sampled households size from the three kebele

Where n=the sample size

N=the population size

e=the acceptable sampling error 90% confidence level

Sample size from each PAs (n1, n2, n3), were taken proportion to the total households (N1, N2, N3). i.e.

$$n1 = \frac{N1 * n}{N}$$

Where N1 is total household in PAs 1, n is a total sampled household from the three PAs and N is total households in the three PAs. Then from each PAs sample size (n1, n2, n3) households were selected from each village of three PAs using stratified proportional random sampling. Accordingly a total of 93(Table 1) HHs were taken to collect data on management and preference of tree species in this study.

Questionnaires on tree species management practices and preference were developed and pretested with A pre-test of the questionnaire on five randomly selected farmers were carried out to verify the information that was collected during the discussion with KI and to verify the quality of the questionnaire in terms of its clarity, suitability of the questionnaires to the respondents, to avoid redundant questions and also to know how much time it needs to complete a questionnaire. For better communication with the respondents, questionnaires were translated into the local language and presented to them, to evaluate clearly their understandings and knowledge. The data collection was done by employing six enumerators, two in each KA. Prior to field work, enumerators were trained and convinced on how to ask question and handle information based on the questionnaire prepared and they were supervised by the researcher.

Table 5: Wealth class distribution of the sampled households in the study villages at Babo Gembel, Western Oromia, Ethiopia (n=93).

Village	Poor	Medium	Rich	Total
Zoni _Haromariam	9	6	3	18
Gute_Korma	5	4	3	12
Lolchisa	8	6	3	17
Sedeqa	7	4	3	14
Melkayida	7	4	3	14
Qiltu_Babo	9	6	3	18
Total	45	30	18	93

To carry out inventory and collect information on farmers' strategy of tree species management, a total of 54HHs (58 % of the total sampled household) for questionnaire survey in the study site (9 HHs from each villages and 3 HHs from each wealth class) were randomly selected. For the assessment of tree species diversity in each coffee farms due to low density of tree species, use of large plot size was used. Accordingly, random plots of 35mx35 were selected (one plot per farm following method of 17]. Other studies in the Western Ghats and elsewhere in tropics have used sample plots ranging from 10 x10 to 10 x 50 m.

1.3. Data Analysis

Although several quantitative descriptions are available for characterizing species diversity, the Shannon-Wiener and Shannon equitability (Evenness) [18, 19] are commonly used and were considered in this study. Richness and diversity of each coffee farms were calculated as the number of species, Shannon and evenness indices. In species diversity study, two components are importa nt: richness and evenness. The species richness refers to the number of species per farm However; this does not indicate the relative proportion or abundance of a particular species on the coffee farm. Hence models that incorporate both evenness and richness of relative abundance were required. Shannon index [20] and Evenness measures (E) which are commonly used tools for these purposes [18] were calculated.

Shannon diversity index (H1) is high when the relative abundance of the different species in the sample is even, and decreases when few species are more abundant than the others. It is based on the theory that when there are many species with even proportions, the uncertainty that a randomly selected individual belongs to a certain species increases and thus the diversity. It relates proportional weight of the number of individuals per species to the total number of individuals for all species [19]. The Shannon-diversity index (H1) was calculated, to analyze the diversity of shade tree species per farm as follows:

$$H^1 = -\sum_{i=1}^{S} P_i \ln P_i$$

Where H' is the Shannon-Weinerindex/ Shannon Diversity Index (H),

Pi = the proportion of individuals or abundance of the *ith* 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 as follows to estimate the homogeneous distribution of tree species on coffee farms

$$E = \frac{H^1}{H\max} = \frac{H^1}{\ln S} = \frac{\sum_{i=1}^{S} pi \ln pi}{\ln S}$$

Where S = the number of species

Pi = proportion of individuals of the *ith* species or the abundance of the *ith* species expressed as proportion of the total abundance.

Thus, the measure of evenness (E) is the ratio of observed diversity to maximum possible diversity. E has values between 0 and 1, where 1 represents a situation in which all species are equally abundant. From these calculations, species richness and heterogeneity as well as density of coffee shade trees were characterized for each farm.

Simpson's diversity index is derived from a probability theory and it is the probability of picking two different species at random [21].
Simpson's diversity (D) is calculated as

$$D = 1 - \sum p_i^2,$$

Where$D$is Simpson's diversity index and p
$i$is proportion of individuals found in the ith species.

Simpson's diversity index gives relatively little weight to the rare species and more weight to the most abundant species. It ranges in value from 0 (low diversity) to a maximum of $(1 - 1/S)$, where $S$is the number of species

1.4. Statistical analysis

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

3. RESULTS AND DISCUSSION

3.1. Species Richness, Abundance and Frequency

Farmers planted or retained different tree species in their coffee farms based on space available and their compatibility with coffee plant and household objectives. The result of this study revealed that, a total 29 tree species categorized under 15 families were recorded in smallholder coffee farms **(appendix 2**) . Similarly, as compared to coffee farms in other regions the number of tree species observed in the study area appears to be comparable. For example, in a study conducted by [22]. a total of 29 tree species have been recorded in the coffee agroforestry of Haro; Manna Woreda of Jimma Zone. Likewise, [23] found 34 tree species in Gedeo coffee agroforestry systems. Moreover,[6]. identified 36 tree species from in the coffee farms of Manasibu districts, western Oromia. On the other hand, the figure on species richness in this study was lower when compared with the earlier report of [17] who reported 107 tree species from shade coffee farms of Veracruz, Mexico.

The overall mean value of number of tree species 4.65 per plot (Table 2) in this study is slightly higher when compared with the work of [24]. reported average species richness of 3.5 per plot from the Northern Tzeltal zone of the State of Chiapas, Mexico. The difference could be associated with differences in socio-economic, cultural setting, geographic location and population pressure to use the resources.

Of the total tree species recorded in this study twenty four (83%) of these species were indigenous and the remaining five (17%) species were exotic to the area **(appendix 2).** In agreement with the present study, other findings elsewhere, [17] reported about 78% of tree species were native in shade coffee farms of Veracruz, Mexico. In other studies reversely, for instance, [25] found the presence of higher number of exotic tree species in coffee farms of Sumberjaya, West Lampung, Indonesia. The high proportions of native tree species in the current study is a reflection of farmer's intimate knowledge of their characteristics and potential uses and the fact that they are better adapted to local climatic conditions. Trees of native species and exotic species were planted because it has economic value as an incentive [5], so that shaded coffee farms could serve as refugia for native tree species [3].

The overall frequency of occurrence of shade tree species varied between 2- 94% of the plot surveyed (Fig.

2). *Cordia africana* was 94% the most frequent tree species occurring in the coffee farms. The other three most frequently appeared tree species were *Vernonia amygdalina, Croton macrostachyus,* and *Albizia gummifera* each occurring 85%, 81% and 77% respectively, and recorded as the most frequently occurred tree species in the surveyed coffee farms. Most of the tree species occurred in the studied coffee farm was frequently cited in other work, such as, *Cordia africana, Croton macrostachyus, Albizia gummifera* [6] who reported four shade tree species with high frequent occurrence from the coffee farms of Manasibu districts, western Oromia.

The overall mean species richness and abundance per farm was 4.65 and 9.5 across the study kebeles (Table 2). There was a significant difference in mean species richness and abundance per coffee farm between the study kebeles ($P < 0.05$). Tree species were more diversified in Haromariam site than the rest sites. The highest tree species richness and abundance at Haromariam site could be associated with the relatively higher level dependency of households on coffee production and establishment deference in coffee based agroforestry practice at that site.

Table 6 Mean species richness and abundance (mean± Std) per plot of tree species in the Coffee farms at kebele level n=54.

	Richness		Abundance	
Kebele	Total	Mean	Total	Mean
Haromariam	22	5.39±1.24[a]	204	11.28±2.08[a]
Boni	18	4.72±0.96[ab]	173	9.67±2.40[b]
Shumeltoke	16	3.83±1.38[b]	136	7.56±2.56[b]
Over all mean	18.67	4.65±1.35	171	9.50±2.77

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

Regarding wealth categories at each village level, a higher mean value of tree species richness and abundance was recorded on farms of rich households than medium and poor households (Table 3). The significant difference of richness among wealth categories of households could be due to the possible effect of wealth of households. For instance, [26] from homgarden of Beseku, Arsi negele Ethiopia stated that wealth status of the household influenced the species diversity of homegardens in that rich class of households was found to own more woody species diversity than the poor class of households. Study's of [17] from southern Ethiopia had also showed that wealth is an important socioeconomic factor influencing tree diversity and farmer choices of crop varieties. The less tree species richness of poor households does not imply that they don't retain or plant tree species. It may be due to the fact that farmers that experience income constraints tend to focus on a few selected species which generate money to satisfy their immediate needs.

Table 7 Mean species richness and abundance of the four study village at each wealth categories in the coffee farms at, Babo_gembel district Ethiopia.

Villages	Wealth	Richness	abundance
Z/haromariam	Rich	5.33±2.08 [a]	14.00±1.00[a]
	Medium	5.67±1.53 [a]	10.33±2.08[a]
	Poor	5.33±1.53 [a]	11.00±2.65[b]
G/korma	Rich	6.00±1.00	12.33±0.58 [a]
	Medium	5.67±0.58 [a]	11.33±0.58 [a]
	Poor	4.33±0.58 [a]	9.00±1.00 [a]
lolichisa	Rich	5.33±0.58 [a]	10.67±0.58 [a]
	Medium	4.67±0.58[ab]	9.00±1.73 [a]
	Poor	3.67±0.58 [b]	8.00±1.73 [a]
Sedeqa	Rich	5.33±0.58 [a]	11.00±1.00 [a]
	Medium	4.00±1.00 [a]	9.33±1.53 [a]
	Poor	5.33±1.16 [a]	9.67±1.16 [a]
Melkayeda	Rich	5.33±1.53 [a]	9.33±2.08 [a]
	Medium	3.33±1.16 [a]	6.00±2.65 [a]
	Poor	3.67±0.58 [a]	7.67±0.58 [a]
Q/babo	Rich	4.33±2.31 [a]	9.33±0.58 [a]
	Medium	3.33±0.58 [a]	7.00±2.00 [a]
	Poor	3.00±1.00 [a]	6.00±3.46 [a]

different letters following vertical mean values indicate significant difference(P<0.05) between categories at each village

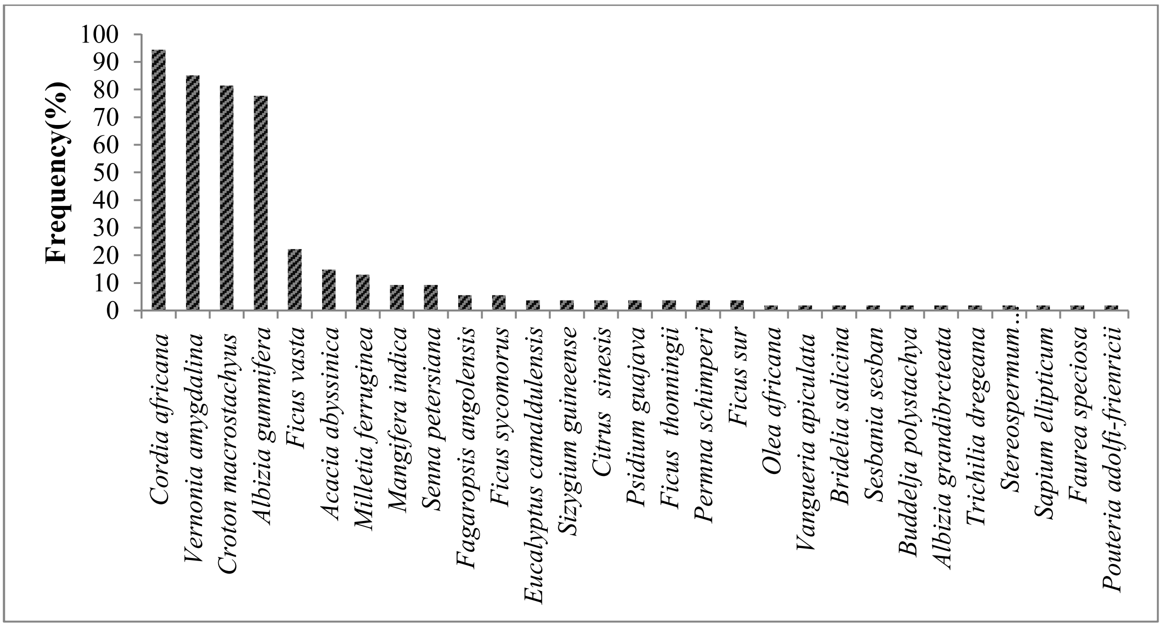

Figure 2. Overall frequent occurrence of tree species in smallholder coffee farms, Babo-Gembel, district, Ethiopia

3.2. Diversity Indices

A comparison of values of diversity indices at the site level showed that higher mean Shannon-Wiener (1.55) and Shannon evenness (0.96) indices were from the Haromariam and Shumeltoke site respectively (Table 4). The highest Shannon diversity at Haromariam site could be due to the higher level of smallholder farmer's dependency on coffee production at that site and their relative higher coffee farm age.

Table 8. Shannon, Evenness and Simpson diversity indices (mean± Std) of tree species in the coffee farms at kebele level n=54

Kebele	Indices		
	Shannon index	Evenness	Simpson index
Haromariam	1.55 ± 0.24^{a}	0.94 ± 0.03^{ab}	0.76 ± 0.06^{a}
Boni	1.42 ± 0.19^{ab}	0.93 ± 0.04^{b}	0.73 ± 0.06^{ab}
Shumeltoke	1.24 ± 0.33^{b}	0.96 ± 0.03^{a}	0.69 ± 0.10^{b}
Over all mean	1.41±0.29	0.94±0.04	0.73±0.08

d*ifferent letters following vertical mean values indicate significant difference (P<0.05) between sites*

Shannon, Evenness and Simpson diversity indices were also calculated for the three wealth classes of the study area at each village (Table 5). From all wealth categories, the highest Shannon diversity index and Simpson index was recorded in G/korma village for rich and the lowest in Q/babo for poor class .There was significant difference in all Shannon, Evenness and Simpson diversity indices ($P < 0.05$) among the three wealth categories at Gute-Korma village where, rich wealth groups had significantly higher Shannon and Simpson diversity indices than poor wealth categories (Table 5). Shannon diversity index does not depend on evenness of species in this study rather it depend on species richness. In support of this finding, [27] reported higher Shannon diversity index were associated with increase in species richness.

Table 9. Shannon, Evenness and Simpson diversity indices (mean±Std) of tree species belonging to three wealth categories in the coffee farm at the study village.

Villages	Wealth class	Shannon index	Evenness	Simpson index
Z/haromariam	Rich	1.56±0.42 [a]	0.97±0.02 [a]	0.76±0.09 [a]
	Medium	1.59±0.22 [a]	0.94±0.05 [a]	0.77±0.04 [a]
	Poor	1.55±0.29 [a]	0.94±0.02 [a]	0.77±0.07 [a]
G/korma	Rich	1.68±0.14 [a]	0.94±0.02 [a]	0.80±0.02 [a]
	Medium	1.63±0.07 [a]	0.94±0.02 [a]	0.79±0.01 [a]
	Poor	1.30±0.10 [b]	0.89±0.03 [b]	0.69±0.03 [b]
lolichisa	Rich	1.53±0.07 [a]	0.92±0.04 [a]	0.76±0.02 [a]
	Medium	1.46±0.12 [a]	0.95±0.01 [a]	0.75±0.03 [a]
	Poor	1.20±0.22 [a]	0.93±0.06 [a]	0.67±0.09 [a]
Sedeqa	Rich	1.54±0.07 [a]	0.92±0.02 [a]	0.76±0.01 [a]
	Medium	1.30±0.24 [a]	0.95±0.04 [a]	0.71±0.07 [a]
	Poor	1.5±0.18 [a]	0.92±0.03 [a]	0.75±0.03 [a]
Melkayeda	Rich	1.59±0.29 [a]	0.96±0.01 [a]	0.78±0.06 [a]
	Medium	1.10±0.36 [a]	0.96±0.05 [a]	0.64±0.12 [a]
	Poor	1.24±0.20 [a]	0.96±0.04 [a]	0.70±0.07 [a]
Q/babo	Rich	1.34±0.47 [a]	0.97±0.02 [a]	0.71±0.11 [a]
	Medium	1.17±0.16 [a]	0.99±0.02 [a]	0.68±0.05 [a]
	Poor	1.00±0.31 [a]	0.95±0.06 [a]	0.60±0.11 [a]

different letters following vertical mean values indicate significant difference (P<0.05) between wealth catacories with in village

3.3. Tree Species Preference of Farmers

The growing of tree species in coffee based agroforestry practice depends on farmers' preference. To evaluate farmers' species preferences, respondents were asked to rank the three most important shade tree species among the species found in their coffee farms and then total relative score was calculated. Accordingly, farmers' selected indigenous and multi-purpose shade tree species in the order of: *Cordia africana> Croton macrostachyus> Albizia gummifera* as most preferred of the various shade tree species in smallholder coffee farms (Table-6). Concerning with tree species preference, it is well documented that farmers grow indigenous multipurpose trees on their farms based on perceived ecological and economic usefulness of the species [17]. The seedling of the tree species in the study area are collected from different sources. The interviewed respondents indicated that 16.13%, 3.23%, 2.15%, and 78.49% seedlings of the tree species planted in the area was obtained from wilding, retained, self-raised and both planted and retained respectively. The most common traditional practice in the study area is that farmers transplant seedling of preferred shade tree species from natural forest in to their coffee farms. Most of the observed species in the coffee farms of the study area were grown in this way (personal communication).According to key informant and focus group discussion response, farmers' decisions to keep or remove trees from the system can be influenced by tree size. For example farmers often refrain from removing relatively large trees like *ficus vasta,* both because of logistical difficulties in removal and to avoid potential damages on their crops and surrounding vegetation when the tree and its branches fall.

Table 10: Preference ranking for shade tree species in coffee farm at Babo-Gembel

Species	Respondent's Number			Relative score			Total relative score
	1st	2nd	3rd	1st	2nd	3rd	
Cordia africana	80	4	-	72.73	0.19	_	72.91
Croton macrostachyus	4	35	25	0.18	14.24	7.53	21.96
Vernonia amygdalina	1	8	10	0.01	0.74	1.20	1.96
Albizia gummifera	4	23	18	0.18	6.15	3.90	10.24
Ficus vasta	1	3	10	0.01	0.10	1.20	1.32
Milletia ferruginea	2	3	4	0.05	0.10	0.19	0.34
Acacia abyssinica	1	3	4	0.01	0.10	0.19	0.31
Sizygium guineense	_	2	3	_	0.05	0.11	0.15
Ficus sycomorus	_	1	2	_	0.01	0.05	0.06
Ficus sur	_	1	1	_	0.01	0.01	0.02
Ficus thonningii	_	3	6	_	0.10	0.43	0.54
Total	93	86	83				

* Relative score was calculated by multiplying the number of respondents in each rank by its proportion (e.g. (80 x 80/93) = 72.73)).

When interviewed HHs and KI are asked to explain the reasons for preferring the trees they had listed, they indicated the goods and services provided by shade trees. The reason most often mentioned referred to the appropriateness of the shade provided to support the growth and development of coffee bushes mentioned for 100% (Figure 3). Farmers considered desirable shade to be that which permitted the passage of light in a mottled pattern and contributed to a fresh microclimate, conditions perceived to support coffee bush growth and development, sustain yields. In their general assessment of socio-economic benefits of coffee shade trees in Ethiopia, [17] mentioned farmers retain shade trees in their coffee farms based on leaf and crown characteristics, tree height and their impact on coffee yield.

Further reasons that reinforced preferences of shade trees included the provisioning of additional goods and services. For example, 80.65 % of the total respondents perceived to benefit soil fertility; 22.58 % of them indicate trees are valuable for soil and water conservation; 35.48 % of them report those trees are a valuable source for timber (Figure 3). This set of goods and services were considered a ‘‘bonus ’’ in addition to the provisioning of adequate shade. Research in Mexico and Central America also described management strategies that seek the gradual replacement of canopy trees by Inga species and other preferred trees were for the benefits associated with coffee production and for the provisioning of secondary goods, such as timber and firewood [31, 32, 7].

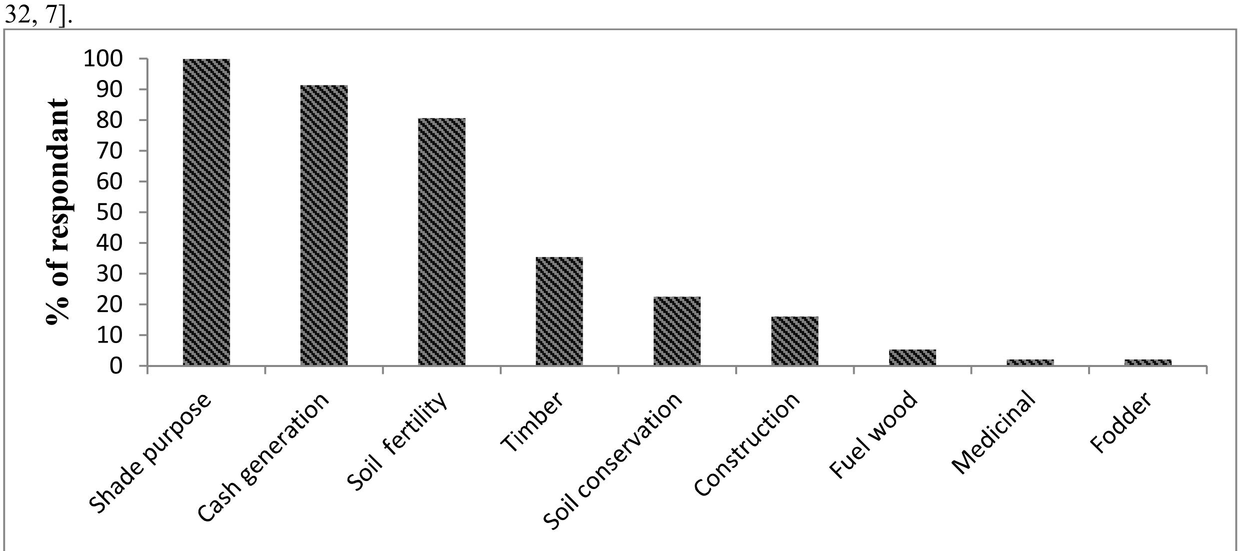

Figure 3**: Reasons for managing woody species and percent of household benefited at the study site**

3.4. Management of tree species in smallholder coffee farms

Farmers in the study area traditionally managed shade tree species in coffee farms to get multiple benefits. Both interviewed respondents and key informants indicated that pruning, thinning, hoeing, weeding/slashing and watering are most commonly used management practices for woody species in the study site (Table 8). In relation to woody species management, [10] reported, there is a long local tradition of managing coffee farms for coffee production by pruning the branch and thinning the canopy through removal of some tree species.

Farmers in the study area not only have profound management activities of which tree species are capable of pruning, but also the time these activities accomplished. All of the respondents and KIs in the study area indicated that the suitable time for pruning shade trees is entry of wet season. Respondents mentioned that the trees pruned in dry season cannot properly sprout and not easily decomposed. Frequency of those management practices ranged from 1 to 3 times per year. Majority of the HHs (81%) carried out those management practices twice a year. Weeding/slashing preformed on average twice a year. The two major weeding/slashing seasons are beginning of the rainy season and beginning of the harvesting season. Few weeks after onset of the main rainy season, most herbaceous vegetation, emerge and compete with coffee and should be cleared. During harvesting as well, weeding is must to create access to pick coffee cherries from the trees, and also to allow picking of early maturing coffee cherries dropped to the ground. Thinning in this case is not to reduce the density of stocking but it is mostly applied to remove old and diseased coffee stems, old trees that have higher competition effect on other; to reduce shade trees, farmers also often debark trees at the bottom, which gradually dries. In most case, application of fertilizer and watering was carried out for *Coffea Arabica* plant. Watering was done to enhance early survival of planted seedlings.

All the interviewed farmers and key informants (KI) indicated that, the purposes of management practices undertaken by households' member in study area were mainly to enhance growth, to provide shade, and to reduce competition (Table 7). Farmers in the study area also indicated that managing trees on their coffee fields by using different management activities were used not only to extract output but also to shape the growth of the tree (through pruning). According to the information recorded from the interviewed respondents, coffee berry diseases, termite infestation, lack of labour and shade tree seedling were some of the challenge that encounter in managing and growing shade tree in the study area

Table 11. Species type and reason of management practices employed by sample households for different shade tree species in Babo-Gembel District, Western Oromia Ethiopia.

Number of households employing various management activities							
Species	Pruning	thinning	hoeing	Weeding	watering	fertilizing*	Reason
Cordia Africana	30	_	1	1	2	_	GR, RC, RS,
Coffea Arabica	5	18	87	89	42	2	GR
Croton macrostachyus	14	15	1	_	_	_	RS, FW, FR
Vernonia amygdalina	3	3	_	_	_	_	GR ,FW, FM
Albizia gummifera	7	3	_	_	_	_	GR, RS, FW,
Ficus vasta	4	_	_	_	_	_	RS, RC,
Milletia ferruginea	6	_	1	1	_	_	RS, FW, RC
Acacia abyssinica	5	_	_	_	_	_	FW, FR
Sizygiumguineense	1	2	_	_	_	_	RS, RC
Ficus sycomorus	_	_	_	_	_	_	RS, RC
Ficus sur	_	_	_	_	_	_	RS, RC
Ficus thonningii	1	1	_	_	_	_	RC, RC,
Total	76	42	90	91	44	2	_
%	81.72	45.16	96.77	97.85	47.31	2.15	_

**Fertilizing refers to the practice of adding manures and other wastes*

4. Conclusion

Coffee farms have the potential to maintain a diversity of tree species outside natural forests. Analysis of the IV of tree species shows the dominance of few trees species in the farms. As the coffee farms age and HHs level of coffee production increased the species diversity increased. Wealth status of the household influenced the species diversity of coffee farms in that rich class of households was found to own more tree species diversity than the poor class of households. Farmers' selected indigenous and multi-purpose shade tree species. Transplant seedling of preferred shade tree species from natural forest in to their coffee farms were the most common traditional practice. Farmers often refrain from removing relatively large trees like *ficus vasta,* both because of logistical difficulties in removal and to avoid potential damages on their crops and surrounding vegetation when the tree and its branches fall. There is a long local tradition of managing coffee farms for coffee production by pruning the branch and thinning the canopy through removal of some tree species. Respondents mentioned that the trees pruned in dry season cannot properly sprout and not easily decomposed. Providing quality seedlings of varies tree species suitable for the area would substantially increase farmers' range of option for planting.

References

[1] Bhagwat, S.A., Willis, K.J., Birks, H.J.B. and Whittaker, R.J., 2008. Agroforestry: a refuge for tropical

biodiversity?. *Trends in ecology & evolution*, *23*(5), pp.261-267.

[2] Chazdon, R.L., Harvey, C.A., Komar, O., Griffith, D.M., Ferguson, B.G., Martínez‐Ramos, M., Morales, H., Nigh, R., Soto‐Pinto, L., Van Breugel, M. and Philpott, S.M., 2009. Beyond reserves: A research agenda for conserving biodiversity in human‐modified tropical landscapes. *Biotropica*, *41*(2), pp.142-153.

[3] Tadesse,W, G., Zavaleta, E. and Shennan, C., 2014. Coffee landscapes as refugia for native woody biodiversity as forest loss continues in southwest Ethiopia. *Biological Conservation*, *169*, pp.384-391.[4]

[4] Gillison *et al*. (2004)

[5] Ambinakudige, Shrinidhi, and B. N. Sathish.,2009. "Comparing tree diversity and composition in coffee farms and sacred forests in the Western Ghats of India." *Biodiversity and Conservation* 18, no. 4 (2009): 987-1000.

[6] Ebisa, L., 2014. Tree species diversity in smallholder coffee farms of Western Oromia Ethiopia. *African Journal of Geo-Science Research*, *3(1):01-03*

[7] Valencia, V., West, P., Sterling, E.J., García-Barrios, L. and Naeem, S., 2015. The use of farmers' knowledge in coffee agroforestry management: implications for the conservation of tree biodiversity. *Ecosphere*, *6*(7), pp.1-17.

[8] Tscharntke et al. 2011).

[9] Everett, Y., 1995. Forest gardens of highland Sri Lanka-an indigenous system for reclaiming forest land. The cultural dimension of development indigenous knowledge systems. London, UK: *Intermediate Technology Publications Ltd*

[10] Tadesse,W, G., Borsch, T., Denich, M. and Teketay, D., 2008. Floristic composition and environmental factors characterizing coffee forests in southwest Ethiopia. *Forest Ecology and Management*, *255*(7), pp.2138-2150.

[11] Perfecto, I., Vandermeer, J., Mas, A. and Pinto, L.S., 2005. Biodiversity, yield, and shade coffee certification. *Ecological Economics*, *54*(4), pp.435-446.

[12] Schmitt, C.B., Senbeta, F., Denich, M., Preisinger, H. and Boehmer, H.J., 2010. Wild coffee management and plant diversity in the montane rainforest of southwestern Ethiopia. *African Journal of Ecology*, *48*(1), pp.78-86.

[13] Aerts, R., Hundera, K., Berecha, G., Gijbels, P., Baeten, M., Van Mechelen, M., Hermy, M., Muys, B. and Honnay, O., 2011. Semi-forest coffee cultivation and the conservation of Ethiopian Afromontane rainforest fragments. *Forest Ecology and Management*, *261*(6), pp.1034-1041.

[14] BGAO , (2016). Babo Gembel Agricultural Office

[15] Crowley 1997,

[16] Yemane , T., 1967.statistics an introductory Analysis,2nd ed ;New York university: New York NY,USA.

[17] López-Gómez, A.M., Williams-Linera, G. and Manson, R.H., 2008. Tree species diversity and vegetation structure in shade coffee farms in Veracruz, Mexico. *Agriculture, ecosystems & environment*, *124* (3), pp.160-172.

[18] Magurran, A.E., 1988. Introduction: measurement of (biological) diversity. Sample chapter one in Ecological diversity and its measurement. Princeton University Press, Princeton

[19] Kent, M.., Coker, P., 1992. *Vegetation Description and Analysis: A practical approach*. John Wiley & Sons.

[20] Shannon, C.E. and Weaver, W., 1949. The mathematical theory of information. The University of Illinois Press.

[21] Krebs, C. J., 1999. *Ecological Methodology*, vol. 2nd, Addison Wesley Longman, Menlo Park, Calif, USA

[22] Mohammed, A.F., 2011. *Perception of Local Community towards Deforestation* (Doctoral Dissertation, AAU).

[23] Yitebitu, M., (2009). The impact of over storey trees on su stainablecoffee (*Coffea arabica)* production in southern Ethiopia. Dissertation, University of Leibniz.

[24] Soto-Pinto, L., Perfecto, I., Castillo-Hernandez, J. and Caballero-Nieto, J., 2000. Shade effect on coffee production at the northern Tzeltal zone of the state of Chiapas, Mexico. *Agriculture, Ecosystems & Environment*, *80*(1), pp.61-69.

[25] Evizal, R., Sugiatno, S., Prasmawati, F.E. and Nurmayasari, I., 2016. Shade tree species diversity and coffee productivity in Sumberjaya, West Lampung, Indonesia. *Biodiversitas Journal of Biological Diversity*, *17*(1) , pp. 234-240

[26] Motuma, Tolera, Zebene Asfaw, Mulugeta Lemenih, and Erik Karltun. "Woody species diversity in a changing landscape in the south-central highlands of Ethiopia." *Agriculture, ecosystems & environment* 128, no. 1 (2008): 52-58.

[27] Tesfaye, A., 2005. Diversity in Homegarden Agroforestry Systems of Southern Ethiopia. Tropical Resource Management Papers, No. 59. 143 pp.

[28] Zebene, A. and. Ågren, I, G., 2007. Farmers' local knowledge and topsoil properties of agroforestry

practices in sidama, southern Ethiopia. *Agroforestry Systems 71: 35-48*
[29] Zebene, A., 2003. *Tree species diversity, topsoil conditions and arbuscular mycorrhizal association in the Sidama traditional agroforestry land use, southern Ethiopia.* Forest Management and Products, SLU. Acta Universitatis Sueciae.Silvestria, *Vol. 263.* 263 pp.
[30] Muleta, D., Assefa, F., Nemomissa, S. and Granhall, U., 2011. Socioeconomic benefits of shade trees in coffee production systems in Bonga and Yayuhurumu districts, southwestern Ethiopia: Farmers' perceptions. *Ethiopian Journal of Education and Sciences*, *7*(1), pp.39-55.
[31] Albertin, A. and Nair, P.K., 2004. Farmers' perspectives on the role of shade trees in coffee production systems: An assessment from the Nicoya Peninsula, Costa Rica. *Human ecology*, *32*(4), pp.443-463.
[32] Bandeira, F.P., Martorell, C., Meave, J.A. and Caballero, J., 2005. The role of rustic coffee plantations in the conservation of wild tree diversity in the Chinantec region of Mexico. *Biodiversity and Conservation*, *14*(5), pp.1225-1240.

Appendix 1. Main criteria used by the key informants (30 informants; 5 informants per village) for classifying households in to three main wealth categories.

	Study villages and rank[a]					
Criteria	Z/haromariam	G/korma	Lolchisa	Sedeqa	Melkayida	Q/babo
Total land size	1	1	1	1	1	1
Size of cattle	3	2	2	2	2	2
Standard of housing	2	3	3	4	3	4
Able to purchase agricultural input	4	4	4	3	4	3

[a] *Within- village the ranking criteria range from 1, being the most important, to 4 being the least important*

Appendix 2. List of tree species with their local, scientific and family names and origin of tree species of the study site

No	Species scientific name	Origin	Family name	local name
1	*Albizia gummifera* (J.F. Gmel.) C.A. Sm.	I	*Fabaceae*	*muka-arba*
2	*Acacia abyssinica* Hochst. ex Benth	I	*Fabaceae*	*Laaftoo*
3	*Albizia grandibracteata* Taub.	I	*Fabaceae*	*Alalee*
4	*Bridelia salicina*	I	*Rubiaceae*	*Gellano*
5	*Buddelja polystachya* Fresen	I	*Loganiaceae*	*Anfaarree*
6	*Citrus sinesis* L.	E	*Rutaceae*	*Burtukaana*
7	*Cordia Africana* Lam	I	*Boraginaceae)*	*waddeessa*
8	*Croton macrostachyus* Del.	I	*Euphorbiaceae*	*Bakkanniisa*
9	*Eucalyptus camaldulensis* Dehnh.	E	*Myrtaceae*	*Bargamoo dimaa*
10	*Fagaropsis angolensis* (Engl.) Milne	I	*Rutaceae*	*Mukkiyyee*
11	*Faurea speciosa* Welw.	I	*Asteraceae*	*Dabaqqaa*
12	*Ficus sycomorus* L.	I	*Moraceae*	*Odaa*
13	*Ficus thonningii* Blume*	I	*Moraceae*	*Dembi*
14	*Ficus sur* Forssk.	I	*Moraceae*	*Harbuu*
15	*Ficus vasta* Forssk.	I	*Moraceae*	*Qilxuu*
16	*Mangifera indica* L.	E	*Anacardiaceae*	*mangoo*
17	*Millettia ferruginea* (Hochst.) Baker	I	*Fabaceae*	*Sottalloo*
18	*Olea africana* Mill.	I	*Oleaceae*	*Ejersa*
19	*Permna schimperi* Engl.	I	*Lamiaceae*	*Urgeessaa*
20	*Pouteria adolfi-frienricii* (Engl.)Boehni	I	*Spotaceae*	*Qaraaroo*
21	*Psidium guajava* L.	E	*Myrtaceae*	*Zyitunaa*
22	*Sapium ellipticum* (Krauss)pax	I	*Euphorbiaceae*	*Bosoqa*
23	*Senna petersiana* Bolle)lock	I	*Fabaceae*	*Ramsoo*
24	*Sesbania sesban* (L.) Merr.	E	*Fabaceae*	*Heennaa*
25	*Sizygium guineense* (Willd.) DC	I	*Myrtaceae*	*Baddeessaa*
26	*Stereospermum kunthianum* Cham.	I	*Bignoniaceae*	*Bosoroo*
27	*Trichilia dregeana Sond.*	I	*Meliaceae*	*Anuunuu*
28	*Vangueria apiculata* K.schum.	I	*Rubiaceae*	*Buruurii*
29	*Vernonia amygdalina* Del.	I	*Asteraceae*	*Eebbicha*