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Full Length Research Paper

Diversity of shade tree species in smallholder coffee farms of western Oromia, Ethiopia

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Shade grown coffee has been promoted as means of preserving biodiversity in the tropics even though expansion of coffee cultivation has been seen as a contributing factor to deforestation and erosion of biodiversity. The study was conducted on diversity of tree species in smallholder coffee farms of Manasibu district, Western Oromia, Ethiopia. The aim of the study was to assess diversity and structure of tree species in smallholder coffee farms as well as farmers management practices in the district. To conduct the study, stratified random sampling method was used. Vegetation data were collected from 74 rectangular plots. The vegetation data was analyzed for tree diversity, Importance value index, similarity coefficient, density, Basal Area, shade cover and other structural parameters. A total of 53 tree species were recorded in which 32 indigenous tree species were common to both forest and coffee farms. Species richness was significantly higher in the adjacent natural forest than in coffee farms. There was significant difference (p<0.05) between Peasant associations (PAs) interims of evenness, coffee shrub density, and tree density. Coffee shrub density was significantly correlated with wealth status. Tree management practices in the study area of coffee farms were more or less the same among the PAs. It was observed that tree species diversity and House Hold (HH) dependency on coffee production increased with the closeness of the PAs to the adjacent natural forest. It was concluded that traditional coffee production system is an important land use system in slowing down loss of biodiversity and should therefore be encouraged.

Keywords: Diversity, adjacent forest, shade trees, smallholder coffee farms, Western (Oromia) Ethiopia.

INTRODUCTION

Previous studies of biodiversity were mainly on undisturbed ecosystems, with less attention given to biodiversity in managed or agricultural ecosystems (Moguel and Toledo, 1999). However, the recently accepted argument is that not only protected areas are enough to ensure biodiversity conservation but also the surrounding agricultural matrix with successful management strategies (Tejeda-Cruz et al., 2010). Widespread agricultural expansion with population growth resulted in the deforestation and biodiversity loss due to lack of appropriate measures or unsustainable management of natural resources like forests. Due to the current rates of deforestation and land degradation in different regions of the world, many species may be lost before they are even known to science (Good, 2004). Even though coffee is under story woody shrub,

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expansion of coffee cultivation is one of the causes of deforestation and biodiversity loss (Ambinakudige and Sathish 2009). However, Agroforestry systems are widely seen as the means that can reduce the impacts of deforestation (Tengnas 1994) through providing eco-agricultural solutions that successfully combine objectives for increased food security and biodiversity conservation gains (Kindtet al. 2008). For instance, coffee shade systems host diverse plant species (Ambinakudige and Sathish, 2009). Accordingly, traditional shaded coffee production system have received considerable attention from conservation organizations in recent years (Perfecto et al. 2005) since the system supports much more biodiversity conservation (Perfecto et al. 1996; Soto-Pinto et al. 2000; Faminow and Rodringuez 2001; Soto-Pinto et al. 2001; Perfecto et al. 2005; Gordon et al. 2007) and cash income generation from the sale of both timber and non- timber forest products (Beer 1987; Beer et al. 1988; Gordon et al. 2007).

Although coffee ranks among the five most valuable agricultural exports from developing nations (Ricketts et al., 2004), there are few studies that describe structural characteristics and woody plant species diversity to define shade grown coffee stands. Particularly in Africa, only few studies of biodiversity in human made landscapes such as coffee agroecosystems have been conducted (Komar, 2006). Likewise, even though coffee production in Manasibu district of Ethiopia is predominated by small scale farming activity, there is no study which documented species diversity, structures, effect of tree species on coffee shrubs, and traditional coffee farm management practices of the study area. Therefore, the aims of the study were:(i) to assess tree species diversity and structural parameters in smallholder coffee farms, (ii) to evaluate the species diversity and similarity between the coffee farms and the adjacent natural forests, (iii) to assess the effect of species richness, shade tree structural parameters, and household (HH) wealth status on coffee shrub density, and (iv) to document farmers management practices in the area.

MATERIALS AND METHODS

Site description

The study was conducted in Manasibu districts, western Oromia, Ethiopia (Fig.1). Manasibu is geographically found at 09º 48'N and 35º 06'E. From the district, mid altitude and lowland areas constitute 68% and 32%, respectively. Mean annual temperature varies from 19 to 22^{o}C. April and May are the hottest months of the area whereas July and August are the coldest months. The mean annual rainfall of the district is 950mm. The altitudinal variation ranges from 1249 to 1933 masl. Fluvisols, Regosols, and Vertisols are the three soil types of the study area.

Agriculture with timber and non-timber forest products is the basis for the livelihood of most of the inhabitants of Manasibu district. The farming system in the area is characterized by crop and livestock mixed farming system; though the level of contribution of each enterprise to the economy of small scale farmers is less understood. Coffee plantations are the major ones in sustaining the life of most households (HHs). Small fragmented forest cover is restricted to the foot hills of some hills, where coffee is commonly grown and where farmers did not convert the forest into other land use type.

The peasant association (PAs) in which the study was conducted were Qorke 01, Guyo SachiLaftoSalga (G/S/L/Salga) and BukeHena (B/Hena). Relative closeness to the nearby adjacent forest and level of household dependency on coffee production was decreasing from Qorke 01 to B/Hena PA**,** respectively. The adjacent natural forests used for sampling purpose were highly disturbed and not demarcated until 2009. These forests are dominated by *Carrisaedulis* particularly in Bembe forest. Most of the trees and shrubs in these forests are encircled by thorny species like *Carrisaedulis*.

Sampling Design

Three PAs and two represent villages were selected purposively based on their relative proximity to road and nearby forests, and also the relative dependency on the farming practice (coffee production), which were supposed to affect diversity of tree species. Stratified random sampling procedure was followed to select target HHs from each of the wealth categories after been ranked with the help of key informants based on amount of coffee and cereal crops produced in quintal per year, number of cattle, landholding size, and type of house. Key informant selection was carried out by following the techniques used by Den-Biggelaar (1996). Subsequently, three representative HHs from each wealth categories (9 HHs) from each village and a total of 54 HHs were randomly selected. Selected HHs were those whose coffee farms were used for data collection. Two disturbed adjacent natural forests were also selected for the reference.

Data was collected by both questionnaire survey and vegetation survey. Questionnaire was distributed to each of the selected coffee producing HHs to identify the farmers management practices of the shade coffee farms from the study area. Due to low density of trees, 54 random plots of 35m x 35m were selected at the center of

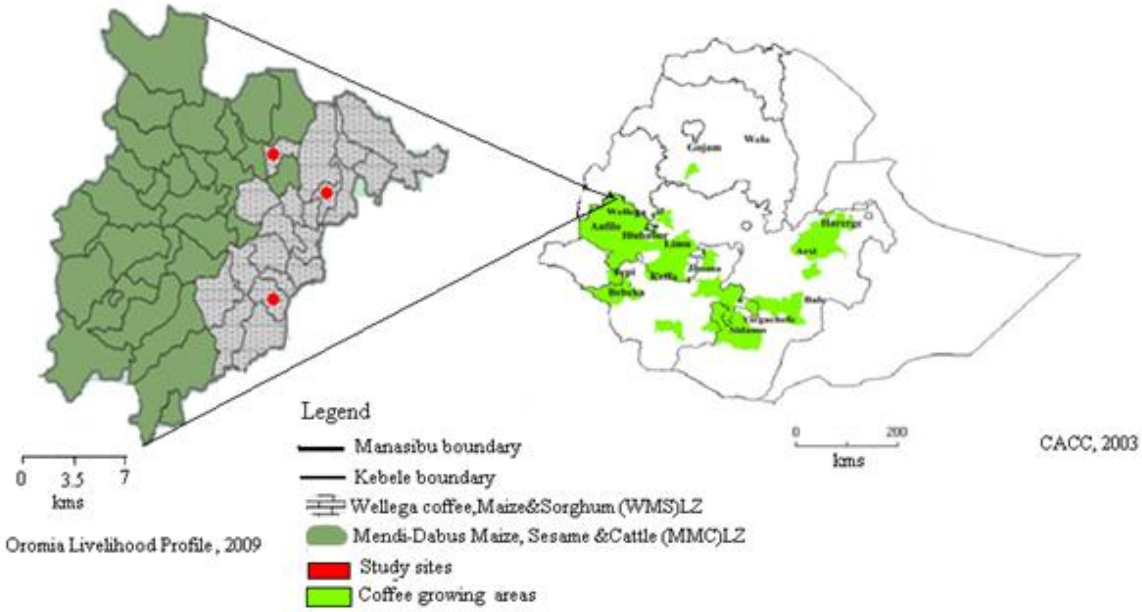

Fig.1. Location of the study area [Manasibu district] from administrative map of Ethiopia showing the main coffee growing areas.

the farms (one plot per farm) following Lopez-Gomez et al. (2008) and Ambinakudige and Sathish (2009). Simultaneously, 10 quadrants of 20m x 20m were selected randomly in each of the adjacent natural forests.
Measurements on tree species of diameter at breast height (dbh or 1.3m) of ≥5cm and height of ≥3m has been conducted in each plot. Plant species below 5cm dbh and 3m height were not considered by this study because they were continuously removed from the system through farm management activities. Diameter measurement was done using caliper or diameter tape. Trees were categorized into 10 diameter classes: 5-15, 15.1-25, 25.1-35, 35.1-45, 45.1-55, 55.1- 65, 65.1-75, 75.1-85, 85.1-95 and >95cm. Height of each tree was measured by hypsometer and classified into nine different height classes: 3-6, 6.1-9, 9.1-12, 12.1-15, 15.1-18, 18.1-21,21.1-24, 24.1-27 and 27.1-30m. Crown diameter was measured by measuring perpendicular canopy rays for each tree by using measuring tape. Coffee shrub abundance from each plot was counted. All tree species ≥5cm dbh were enumerated and identified by referring to the Flora of Ethiopia and Eritrea (Edwards et al. 1995; Edwards et al. 1997; Edwards et al. 2000; Hedberg et al. 2003; Hedberg et al. 2004; Hedberg et al. 2006).

Data analysis

The species diversity and similarity were estimated using the Shannon diversity index, Shannon Evenness and Sorensen similarity index, respectively. Whereas, the vegetation structure was estimated using the density, basal area, per cent shade cover, diameter and height. Species richness, Shannon diversity index, and Shannon Evenness were analyzed to evaluate the change in tree species between the adjacent forest and coffee farms. These parameters were also compared among PAs and wealth classes to evaluate the effect of PAs position and status of household on tree species diversity in the coffee farms. Similarly, both tree structure and coffee shrub density in the coffee farms were compared between the PAs, and among the wealth classes. Tree diameter and height were computed only in the coffee farms. The relative importance of each 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 (Kent and Coker, 1992) after pooling the data from each plot for each species to evaluate the dominance of a species in the shade coffee system.
Per cent shade cover was calculated after first calculating crown area and crown diameter of each over story tree as indicated below. Crown cover of each tree in a plot was calculated and changed to percentage canopy cover.

$$\text{Per cent shade cover} = \frac{\sum_{i=1}^{S} \text{CA}}{\text{sample area}} \times 100 \qquad \text{..........Equation 1}$$

CA= crown area of individual tree (m^2); S= number of individuals in the sample plot

Table 1. Diversity indices, species richness, and tree density in the coffee farms and the adjacent natural forests (mean ± SD).

Land use	Density ha^{-1}	Species richness		Diversity indices	
		Total	mean	H'	E
Coffee farms	123.36(±60.96)[b]	36	6.5(±2.33)[b]	1.63(±0.42)[b]	0.91(±0.07)[b]
Natural forests	182.45(±24.74)[a]	49	14.8(±3.14)[a]	2.56(±0.24)[a]	0.96(±0.02)[a]
F-value	35.16	152.5		86.8	7.2
P	<0.000	<0.000		<0.000	<0.008

Means with the same letter in the column were not significantly different at P=0.05

Sorensen similarity index (Ss) measures how the floristic compositions of different coffee farms or land use systems are similar. Species similarity analysis was complemented by calculating the floristic similarities between the coffee farms and the adjacent forests; and among PAs using Sorensen's similarity index (Magurran 1988):

$Ss = \frac{2C}{A+B}$……………………………..Equation2

C= the number of species common to both sites; A= the number of species present in one of the sites to be compared; B= the number of species present in the other site.

Statistical analysis

Descriptive statistics were used to present the results. The results were subjected to one-way ANOVA Tukey's test to compare whether there was significant mean differencein tree species diversity betweenthe land uses, among PAs and wealth categories. The result was also subjected to Pearson correlation using SAS version 9.

RESULTS AND DISCUSSION

Tree species diversity

A total of 53 tree species were recorded from the coffee farms and the adjacent forests, of which 49 were native and 4 were exotic species. Therewas higher tree species richness recorded in the adjacent forests (49) than in the coffee farms (36) (Table1) which is comparable with the results of the studies by Hylander and Sileshi, (2009) and Ambinakudige and Sathish (2009) where forest and coffee home garden; sacred forest and coffee farms (redeemed and unredeemed coffee plots) were compared, respectively. Contrary to the current study, Lopez-Gomez et al. (2008) recorded higher number of tree species in the coffee farms than in the adjacent forest. Similarly, Shannon diversity index and Shannon evenness were also higher in the adjacent forests. This difference may be explained in terms of the difference in the management practices in the two land uses. Coffee farms were generally characterized by selective retention of some amount of over story trees as shade tree while there may not be such intentional management in the adjacent natural forests. The dominance of some species in the coffee farms can be explained by the importance attached to those species by the farmers for additional purposes like timber extraction, medicinal value, honey production, fodder for their cattle, fuel wood and organic matter production.

The adjacent natural forest is generally expected to have higher number of tree species than coffee farms since coffee farms need continuous management that eliminates seedling, sapling and shrubs to create free space for coffee shrubs so as to reduce competition. Tadesse (2003); Schmitt (2006); Feyera and Denich (2006) also reported higher plant species diversity in forest coffee than in the semi forest coffee system due to the shade reduction. However, coffee production, which is often considered a threat to natural forest biodiversity have important contribution to tree species diversity (Ambinakudige and Sathish, 2009).

In the coffee farms of the current study, although average number of tree species and Shannon diversity index were not significantly different among the PAs, it was slightly higher in Qorke 01 PA than the others (Table 2). The lowest species diversity in the B/Hena coffee farms may be explained in terms of uneven distribution of shade tree species across the sampled coffee farms, the relatively less dependency of the resident farming HHs on coffee production since cereal production was equally important and perhaps also due to the relatively longer distance from the adjacent forest. Whereas, the highest tree species diversity in Qorke 01 coffee farms may be explained in terms of more dependency of dweller

Table 2. Species richness, diversity indices and structural variables of trees and coffee shrub density (mean ± SD) in the coffee farms at PA level n=54.

Variables	G/S/L/Salga	B/Hena	Qorke 01	F-value	P
Total S	29	26	25		
Mean S	6.61(±2.87)[a]	5.89(±2.25)[a]	7.00(±1.75)[a]	1.04	0.361
H'	1.59(±0.52)[a]	1.50(±0.40)[a]	1.81(±0.26)[a]	2.71	0.076
E	0.90(±0.07)[ba]	0.88(±0.10)[b]	0.95(±0.03)[a]	3.76	0.029
BA	16.13(±8.44)[a]	13.52(±7.83)[a]	10.54(±4.59)[a]	2.75	0.073
Coffee shrub density ha^{-1}	3541(±976.35)[b]	3965(±1061.26)[b]	4752(±621.33)[a]	8.28	0.001
Tree density ha^{-1}	120.18(±42.07)[ba]	155.10(±84.28)[a]	94.78(±27.74)[b]	5.14	0.009
Shade %	66.01(±26.01)[a]	48.99(±19.78)[a]	54.63(±19.19)[a]	2.48	0.093

S- Species richness, BA- basal area
Means with the same letter in the row were not significantly different at P=0.05

Table 3. Species richness, diversity indices and structural variables of tree species, and coffee shrub density (mean ± SD) in the coffee farms among wealth classes n=54.

Parameters	Poor	Medium	Rich	F-value	P
Total S	22	30	26		
Mean S	5.44(±2.15)[b]	7.28(±2.16)[a]	6.78(±2.46)[ba]	3.38	0.046
H'	1.57(±0.45)[a]	1.76(±0.37)[a]	1.57(±0.41)[a]	1.27	0.289
E	0.94(±0.05)[a]	0.91(±0.08)[a]	0.88(±0.09)[a]	2.42	0.099
Coffee shrub density ha^{-1}	3689(±1022)[a]	4204(±1008)[a]	4366(±969)[a]	2.24	0.117
Tree density ha^{-1}	97.51(±34.69)[a]	131.97(±59.35)[a]	140.59(±75.89)[a]	2.68	0.078

Means with the same letter in the row were not significantly different at P=0.05

farming HHs on coffee production and more closeness of the PA to the adjacent natural forest. Furthermore, the results of the current study indicated that farmers species selection, preservation and management of coffee shade trees were more or less similar across the study sites. However, tree species diversityin the coffee farms of medium HH wealth class was higher than that recorded from the poor and rich wealth class (Table 3). The result implies that tree species composition and diversity in the coffee farms were not linear with HH wealth status for this particular study. The finding of this study was in line with that of Motuma et al. (2008) and contrary to that of Zebene (2003).

The results of the current study indicated that there was a high species overlap between the adjacent natural forests and the coffee farms. Sorensen's similarity index between the coffee farms and the adjacent natural forests was 0.75 indicating high overlap between the two land use types since most of the tree species in the coffee farms were native and remnants from the conversion of natural forest to coffee farms. Hylander and Sileshi (2009) also reported similar results from forests and coffee home gardens in that most of the shade trees in the coffee home gardens were trees commonly found in forests. In the contrary, Mendez et al. (2007) reported lower similarity in species composition between shade coffee cooperatives and forest sites in El Salvador. Out of a total of 53 tree species, 32 (60.4%) were common, while 17 (32.1%) and 4 (7.5%) were unique to the adjacent natural forest and coffee farms, respectively. In the adjacent natural forests, all of the unique tree species were indigenous as might be expected, while the unique species in the coffee farms were exotics. Those unique tree species restricted to the natural forests were the least preferred by the farmers primarily because of their unsuitability for shade and generation of income; whereas those species unique to the coffee farms were purposefully introduced fruit tree species. Ambinakudige and Sathish (2009) also reported similar results from sacred grove and coffee farms in India.

Regardless of the difference in tree species diversity, there was high species overlap between PAs. Accordingly, it ranged from 69 to 81% between sites (PAs). The highest similarity (0.81) in species

Table 4. IVI of total tree species recorded in the surveyed coffee farms (n= 54).

Species scientific name	Abundance	RF %	RDe%	RDo%	IVI
Acacia abyssinica	28	5.556	3.074	4.093	13
Albiziagrandibracteata	26	4.094	2.854	2.269	9
Albiziagummifera	109	10.527	11.965	20.519	43
Apodytesdimidiata	12	3.217	1.317	1.254	6
Bersamaabyssinica	32	4.094	3.513	2.789	10
Brideliamicrantha	6	1.462	0.659	0.239	2
Bruceaantidysenterica	1	0.877	0.11	0.142	1
Capparisfascicularis	6	1.17	0.439	0.157	2
Citrus sinesis	7	1.17	0.768	0.055	2
Cordiaafricana	168	14.036	18.441	24.887	57
Croton macrostachyus	163	12.866	17.892	13.397	44
Dovyalisabyssinica	8	2.047	0.878	0.482	3
Ekebergiacapensis	2	0.585	0.22	0.022	1
Elaeodendronbuchananii	3	0.585	0.329	0.17	1
Entadaabyssinica	2	0.585	0.22	0.007	1
Fagaropsisangolensis	1	0.292	0.11	0.134	1
Faureaspeciosa	2	0.585	0.22	0.01	1
Ficussur	9	2.339	0.988	1.159	4
Ficusthonningii	6	1.754	0.659	0.689	3
Ficusvasta	17	4.094	1.866	10.42	16
Maesalanceolata	8	1.754	0.878	0.672	3
Magniferaindica	15	2.047	1.647	2.393	6
Millettiaferruginea	29	5.263	3.183	2.931	11
Oleacapensis	1	0.292	0.11	0.011	0
Perseaamericana	1	0.292	0.11	0.02	0
Piliostigmathonningii	1	0.292	0.11	0.167	1
Psychotriaorophila	3	0.877	0.329	0.33	2
Sapiumellipticum	18	4.386	1.976	3.943	10
Sennapetersiana	3	0.585	0.329	0.279	1
Sesbaniasesban	4	0.877	0.439	0.028	1
Steganotaeniaaralaceae	3	0.292	0.439	0.297	1
Stereospermumkunthianum	1	0.292	0.11	0.009	0
Syzygiumguineense	7	1.17	0.768	1.217	3
Tecleanobilis	6	0.877	0.659	0.155	2
Vangueriaapiculata	5	1.17	0.549	0.203	2
Vernoniaamygdalina	199	7.603	21.844	4.452	34

composition was observed between G/S/L/Salga and Qorke 01 PAs, which were relatively farther apart than between B/Hena and Qorke 01 (0.78) those were relatively closer. The results suggest that distance between the PAs did not influence the variation in species composition among the PAs because the highest similarity was observed from those are apart.

The IVI of a species increases with the preference the farmers give to the species. Use value, source of the seedling and position of the coffee farms resulted in the difference in importance of tree species in the coffee farms. *C.africana*(57), *C.macrostachyus* (44), *A.gummifera* (43), and *V.amygdalina* (34), respectively were found to be the four most important species based on their IVI (Table 4). The above mentioned tree species are generally common in most coffee growing regions of the country as coffee shade trees. The finding of the current study was thus in line with previous study of Feyera (2006) and Yitebitu (2009). Furthermore, although the total tree species diversity in coffee farms could be high, some species may be preferred more by the farmers to the rest of the species retained in their coffee farms (Soto-Pinto et al. 2001) due to that shade trees provide several economic and ecological benefits (Yadessa et al. 2008)

Generally, the most important tree species are those most common and abundantly retained in agroforestry system (Tesfaye 2005; Motuma et al. 2008). Farmers' knowledge about the relative advantages of different tree species such as provision of balanced shade for coffee shrubs, rapid rate of decomposition of leaf litter to improve soil fertility and availability of seedlings in their vicinity plus additional values (cash, medicinal and fodder) may have been the major causes of the difference in the importance of the tree species in the study area.

Vegetation structure

Tree density per hectare in the coffee farms was significantly lower than in the adjacent natural forests (Table 2) as also reported from Mexico (Lopez-Gomez et al. 2008) and India (Ambinakudige and Sathish 2009). The mean tree density in the coffee farms in the current study was much higher than the one reported by Tadesse et al. (2001) which was 60 trees ha^{-1} (≤10cm dbh) in the Ethiopian traditional garden coffee farms, while much lower than those of reported by Soto-Pinto et al. (2000) and Soto-Pinto et al. (2001) inMexicowhich were 464 and 371.4 ha^{-1}, respectively. The recommended tree density per hectare in coffee farm is to the minimum 70 individual trees with 12 native tree species (SAN 2005). However, the minimum tree density in the coffee farms was 49 individuals/ha from the current study.

There was significant difference in mean tree density and coffee density among the PAs, the highest tree density and coffee density was observed in B/Hena and Qorke 01 PA, respectively (Table 2). With respect to the highest tree density in B/Henawas due to the comparatively less intensive management of coffee farms since the high income of B/Hena farming HHs is from cereal production. Feyera (2006) also discussed continued management suppresses tree regeneration and reduces tree density, while promoting a high number of bigger shade trees over coffee. The mean density of coffee shrub of the study area was 4086 ha^{-1} which is higher than what was reported by Tadesse et al. 2001 (1000 ha^{-1} in Hararghe to 3500 ha^{-1} in south and southwestern parts of Ethiopia). The result of the current study was also higher than those of Soto-Pinto et al. (2000) from Mexico (800 to 3500 coffee shrubs ha^{-1}). Previous studiesof Lopez-Gomez et al. (2008) and Asteggiano, (2008) reported that asmanagement of shade coffee farms increase,coffee shrub density also increase. In the study area, coffee shrub is traditionally planted in an irregular pattern instead of row planting; and maintaining such a high coffee shrub density is perhaps a strategy for countering the effects of the widespread coffee blight disease and termite infestation in the area.

Among the PAs, the highest shade cover was recorded from G/S/L/Salga (66.01%) followed by Qorke 01 (54.63%) (Table 2).G/S/L/Salga was characterized by the dominance of relatively larger trees whose crowns provide large shades. This was also supported by the highest basal area. Correlation between shade cover and basal area ($r = 0.59$; $p = 0.000$) also confirms this relationship. Finding of this was inline with previous studies of Mendez et al. (2007); Asteggiano (2008); Mendez et al. (2009); Yitebitu (2009). As far as the relationship between shade cover and tree density is concerned, it was observed in the current study (Table 2) and also from other study (Soto-Pinto *et al*., 2000) that shade cover does not necessarily correspond to tree density.

Farmers manage the shade tree canopy to balance optimum shade for coffee production and obtain tree products. This involves a yearly pruning of the shade tree canopy, aiming to leave 40–50% shade cover (Mendez et al. 2007) for maximum coffee yield (Soto-Pinto et al. 2000; Yitebitu 2009). The minimum recommended shade cover over coffee shrubs was 40% of the land (Faminow and Rodriguez, 2001; SAN, 2005); however, it may differ from country to country. Themean per cent shade cover in the coffee farms of the current study sites was 58.63% which is higher than the minimum recommended shade cover for the coffee land.

The largest tree diameter and height in the coffee farms were found to be 167cm and 30m, respectively.The average dbh and height of trees in the surveyed coffee farms was 31.5cm and 12.36m, respectively. Most of the trees in the coffee farms had dbh of ≤ 45cm (Fig. 2) which accounted for 79.7% of all the trees in the farms. *F.vasta, A.gummifera, and C.africana* trees had higher dbh than the others. According to Soto-Pinto *et al*. (2001) most of shade components were in the range of <20cm dbh. Most of the trees had height of ≤15m which accounted for 73.2% of the trees in coffee farms (Fig.2). Therefore, there was higher tree abundance at both the lower diameter and height classes.

Effect of shade tree species richness, tree structural parameters, and HH wealth status on coffee shrub density

Coffee shrub formed the under story stratum in the coffee farms. From this study, there was no significant correlation between coffee shrub density and tree species richness ($r = -0.022$; $P = 0.437$). This indicates that, density of coffee shrubs was not significantly influenced by tree species richness in the coffee farms. Rather influenced by different interactions between shade trees and coffee shrubs in addition to management practices (Beer et al. 1998). Similarly, there were no significant positive relationship between coffee shrub density and shade cover ($r = 0.17$; $P = 0.110$) and between coffee shrub density and tree density ($r = 0.09$; $P = 0.256$), but according to Yitebitu (2009), there was strong negative correlation ($r = -0.828$, $P<0.0001$) between tree density and coffee density. According to Diriba et al. (2007) degree of shading had effect on

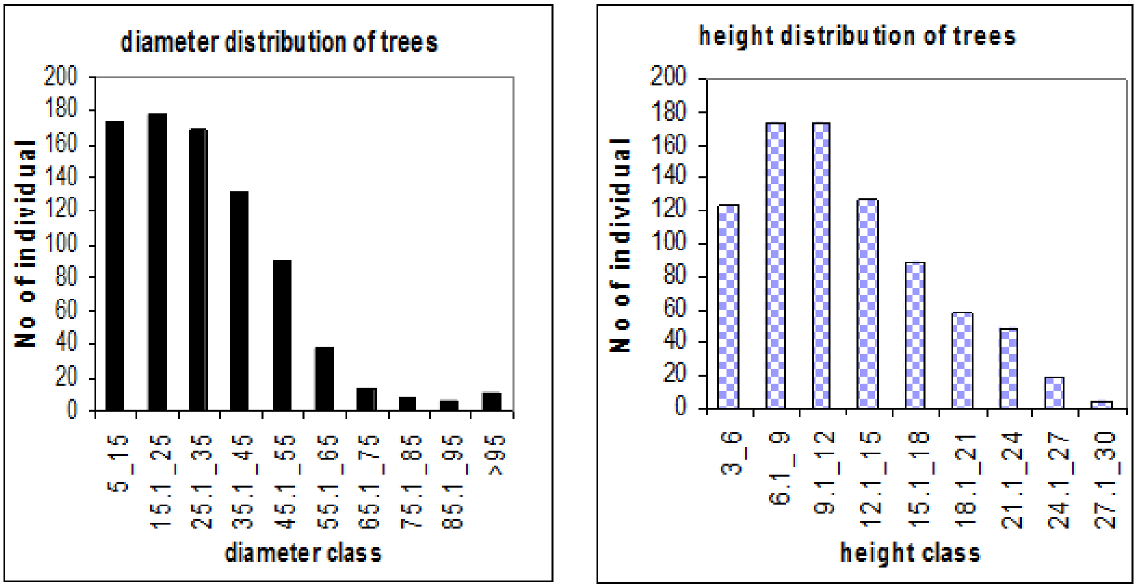

Fig. 2. Height and diameter class distribution of trees in the coffee farms.

counts of coffee shrubs. However, HH wealth status had significant positive correlation with coffee shrub density ($r = 0.27$; $p = 0.023$) and with tree density ($r = 0.29$; $p = 0.016$) in coffee farms; with the highest tree and coffee shrub density corresponding to rich HHs and the lowest to Poor HHs.

Management practices in coffee farms

Farmers' management practices of coffee farms influenced tree species both positively and negatively. Shade trees were planted and retained in coffee farms for dual purpose they have. Therefore, shade trees are treated positively than other tree species, those excluded from coffee farms due to their negative effect on coffee production. Few shade tree species were preserved in abundantly, whereas more tree species were retained rarely. The preference of shade trees by farmers was variable among the most common trees in the coffee farms of the study area. Accordingly, the most preferred tree species were *C. africana* (100%), *A. abyssinica* (66.67%), *A.gummifera* (52.78%), and *V. amygdalina* (16.67) while *Sesbania sesban* (5.56%), *M.indica* (5.56%), *Senna petersiana* (2.78%), *Albizia grandibracteata* (2.78%), and *Sapium ellipticum* (2.78%) were the least preferred shade trees.

There were different management activities that are commonly applied in coffee farms to maintain continuous coffee production. The long time tradition in the area favors incorporation of selected native tree species for shade into the coffee farms. Therefore, most farmers maintained trees in the coffee farms not only for shade but also for their additional values such as economic importance (sell of timber and fruits), source of food (fruits), fuel wood, fodder, soil and water conservation, andmedicinal value.Earlier study of Soto-Pintoet al. (2000) also indicated similar benefit of shade trees and shrubs.Almost all coffee farmers in the study area employed similar management practices such as thinning shade trees, pruning both shade trees and coffee shrubs, weeding, fertilizing, and hoeing to control the interaction between coffee shrub and shade trees, and also to make coffee production sustainable through reducing competition among the components, and controlling shade cover per cent (Table 5). Similar management practices were recorded by Mendez et al. (2009) from cooperatives coffee plantations in western El Salvador.

Coffee shrubs and shade trees are actively pruned in most of the plantations where these activities are carried out in irregular cycles (Hernandez-Martinez et al. 2009). However, management approaches related to shade tree density and diversity, pruning of trees and coffee bushes, and weeding have been shown to affect soil chemical and physical characteristics (Mendez et al. 2009). Frequency of these management practices ranged from 1 to 3 times per year. Majority of the HHs (63.8%) carried out these activities twice a year. About a third of the HHs (33.33%) carried out the activities three times a year, while only 2.78% of HHs carried out once a year. Weeding (slashing) and hoeing performed on average

Table 5. Common tree management practices in the coffee farms of the study area (n = 54).

Management practices	Responded HHs (%)	Reasons for practicing	Responded HHs (%)
Thinning	88.89%	For better growth	97.22%
Pruning	83.33%	To reduce competition	91.67%
Weeding	58.33%	To reduce shade	80.56%
Fertilizing	5.56%		
Hoeing	97.22%		

twice a year. When a new coffee farm is established, the density of shade trees is generally high but with time shade trees are thinned out to reduce competition. Pruning coffee shrubs occurs when they get old in order to encourage coppicing and thus to improve production.

CONCLUSION

Shade coffee production system play important role in harboring various tree species. The highestindigenous tree species composition similarity between coffee farms and adjacent natural forests indicates the conservation role being played by shade coffee production systems. As the proximity of the PAs to the adjacent natural forest increased, tree species diversity in the coffee farms also increased. Similarly, as level of HH dependency on coffee production increased, diversity of tree species also increased. However, HH wealth status could not be the cause for tree species diversity in the coffee farms. In the study area, tree density and shade cover had no significant positive correlation with coffee shrub density in the coffee farms. The relationship among BA, tree density, coffee shrub density and shade cover was not always linear. There was no significant negative correlation between tree species richness and coffee shrubs density. However, adding tree species without knowing its suitability may affect the coffee shrub density in the coffee farms negatively due to their hindrance behavior.

RECOMMENDATIONS

In the face of the alarmingly high and unabated deforestation, and from biodiversity conservation point of view, converting degraded and highly disturbed natural forests to shade coffee system appears to be a better option than converting them into a cereal production system when it comes to choosing between the two options. From biodiversity and environmental points of view, smallholder shaded coffee farms should be encouraged through a certification programme. Shade coffee farms of lower tree density with very few native species should retain or planted to the minimum requirement. Similarly, per cent shade cover in coffee farms with lower (<40%) should be increased at least up to the moderate shade levels (40-50%) for better shade coffee production. to provide optimal shade environment for coffee shrubs, tree density or shade cover should be managed.

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