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Woody species diversity under natural forest patches and adjacent enset-coffee based Agroforestry in the Midland of Sidama Zone, Ethiopia

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Agroforestry lands will be the most beneficial to the long-term preservation of biodiversity through preserving native species of plants and animals in tropical countries. Despites its vital roles, the contributions of agroforests and forest patches for biodiversity conservation in Ethiopia have few studded. The aim of this study was to investigate status of woody species diversity in natural forest patches and adjacent Enset-Coffee based agroforestry (ECAF) with particular emphasis on their contributions to biodiversity conservation in midland of Sidama zone, Ethiopia. The two study sites (Wonsho and Shebedino districts) were selected purposively based on presence of forest patches and extensive practices of ECAF. Similarly, the three kebele in each sites were selected based on the presence of natural forest patches. A total of 96 quadrats (48 in each systems), having 20 m x 20 m area were systematically sampled. Our results show that a total of 75 different woody species categorized under 31 families were recorded, of which 43 species under 30 families from the natural forest patches and the remaining 32 species under 21 families from ECAF. Twenty two woody species belonging to 15 families were common to both the natural forest patches and ECAF that makes 58.67% of similarity in woody species composition. Euphorbiaceae family had the highest number of woody species both in the natural forest patches and ECAF. Shannon and Simpson diversity indices of woody species from natural forest patches were significantly ($p < 0.05$) higher than the ones from ECAF. Of all woody species identified, 86.67% were native. Finally, it is concluded that ECAF play a major role in the conservation of native woody species.

Key words: Biodiversity, conservation, native, woody species, similarity.

INTRODUCTION

Natural habitats in the tropics are being converted to agricultural land faster than in any other biome (Whitmore, 1997). These changes can result in the loss of population and species. Consequently, the need for immediate action to design effective strategies to conserve biodiversity is given an attention worldwide. Scientists and policy makers are becoming increasingly aware of the role agroforestry plays in conserving biological diversity in both tropical and temperate regions of the world. The mechanisms by which agroforestry systems contribute to biodiversity have been examined by various authors (McNeely, 2004; Schroth et al., 2004; Harvey and Villalobos, 2007). In general, agroforestry plays five major roles in conserving biodiversity: (1) provides habitat for species that can tolerate a certain level of disturbance; (2) helps preserve germplasm of sensitive species; (3) helps reduce the rates of conversion of natural habitat (4) agroforestry provides connectivity by creating corridors between habitat remnants and (5) helps conserve biological diversity by providing other ecosystem services such as erosion control and water recharge. Different authors also promoted *circa situm* conservation via an agroforestry system high in agricultural landscapes ((Boffa et al., 2005; Philpott et al., 2008). This approach focuses on sustainable conservation and utilization of the species. Retention of forest species in agricultural landscapes enhances biodiversity conservation at both species and landscape level (Herve and Vidal, 2008). The preservation of biodiversity was not limited in agroforestry lands. Remnant trees (forest patches) also play an important role in conserving biodiversity within agricultural landscapes, because they provide habitats and resources that are otherwise absent from agricultural landscapes (Harvey and Haber, 1999).

Agroforestry practice in the tropics and sub-tropics started many years ago (Kumar and Nair, 2004; McNeely and Schroth, 2006). In Ethiopia, agroforestry emerged together with agriculture not more than 7000 years ago (Brandt, 1984). Trees and shrubs have been retained and planted on agricultural landscapes (Asfaw and Nigatu, 1995; Kanshie, 2002). The historical development of our study agroforestry sites is related to the domestication of natural forest landscapes and intensification to agricultural lands (Negash and Achalu, 2008).

Originally, the sites were dominated by mid-altitude species, such as *Syzygium guineense, Pod carpus falcatus, Millettia ferruginea, Cordia africana, Croton macrostachyus, Aningeria adolfi-friederici* and *Erythrina* spp (Asfaw, 2003).

Despite of its vital role for biodiversity conservation of agroforestry and forest patches in tropical country, in Ethiopia the contribution of agroforests and forest patches on biodiversity conservation aspects has less emphasis and documentation (Negash et al., 2012b).

Therefore, the aim of the present study was to assess the status of woody species diversity in natural forest patches and adjacent Enset-Coffee based agroforestry (ECAF) with particular emphasis on their contribution to biodiversity conservation in the Midland of Sidama zone, Ethiopia.

MATERIALS AND METHODS

Study area

The two study sites, Wonsho and Shebedino district (here after woreda) were situated in Sidama Zone of Ethiopia (7°00'–7°06' N and 38°-34' E 38°_37' E) of southern Nations, Nationalities and regional state (Figure 1).

The topography of the districts is generally characterized by hilly (60%), flat (15%) and mountains (25%) and the elevation ranges from 1500 m to 3027 m.a.s.l (Asfaw, 2003).

The soils at the study sites are mainly classified as Nitosols (Asfaw, 2003). The average annual rainfall of Shebedino woreda is 1300-1500 mm and temperature is between 18-25°C (Negassa, 2005). Thirty three percent of the Woreda is classified as Dega (> 2300 m.a.s.l.) and the remaining 67% is Weina-dega(1500 – 2300 m.a.s.l)

The mean annual temperature and rainfall of Wonsho woreda range from 20-25°C and 1200 - 1600 mm, respectively (Negassa, 2005). This study area is largely found in the agro climatic zone of Weina-Dega (59%) and Dega (41%).

Method of data collection

Site selection

The two sites (Wonsho and Shebedino) were selected based on the presence of natural forest patches and intensive practices of ECAF. Those forest patches are surrounded by ECAF and settlements. At each site, two kebele from Shebedino and one kebele from Wonsho having extensive agroforestry practices and the presence of forest patches were purposively selected. Hence, two of the natural forest patches namely “Arossa", "Akako" were selected from Garagalo Kebele, and Telamo Kebele in Shebedino woreda, respectively. "Abo" forest patch from Bokaso Kebele in Wonsho woreda was selected. The native forest patches are separated by agroforests that have been practiced for long period of time, and settlements. The average distance between the three patch forests is 15 km. Arosa, Akako and Abo natural forest patches are about 2.12 ha, 1.8 ha and 32.5 ha areas, respectively.

Sampling techniques

In Sidama zone, south Ethiopia, agroforestry have been practiced for long period of time reserving the original *podo- coridia* dominant natural forest. After clearing of the forests for purpose of settlements, monocropping and agroforestry practices, the three patch forest has been left for traditional religious purposes. The three patch forests have similar ages and homogenous habitat natures, because they are previously considered as one natural forest. Similarly, the practices of ECAF surrounding the forest patches also have homogenous nature which uses Enset as the staple food and main crop in the areas. Because of this, systematic sampling method was employed for this study. The sampling procedures focused on identification of area having forest patches and the orientation of each forest patches and adjacent ECAF (Figure 2). Each forest was divided into four parts where one line run through the center from east to west and the other running from south to north (Figure 2). In order to locate quadrat for adjacent ECAF, the four transect lines was extended up to 2 km from

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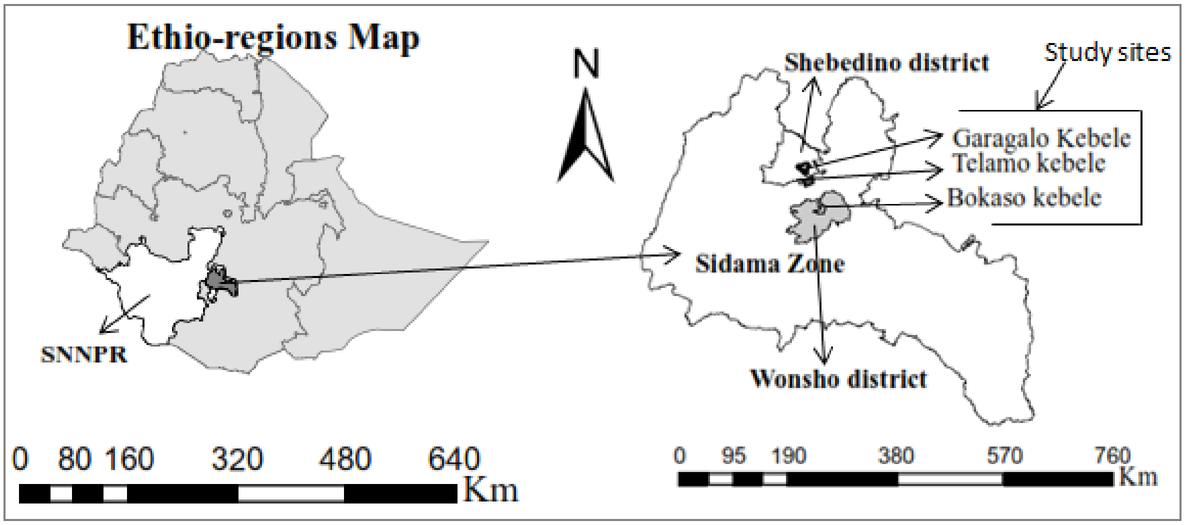

Figure 1. Map of study of sites in midland of Sidama**,** Southern Nations, Nationalities, and People Regional state (SNNPRs), Ethiopia.

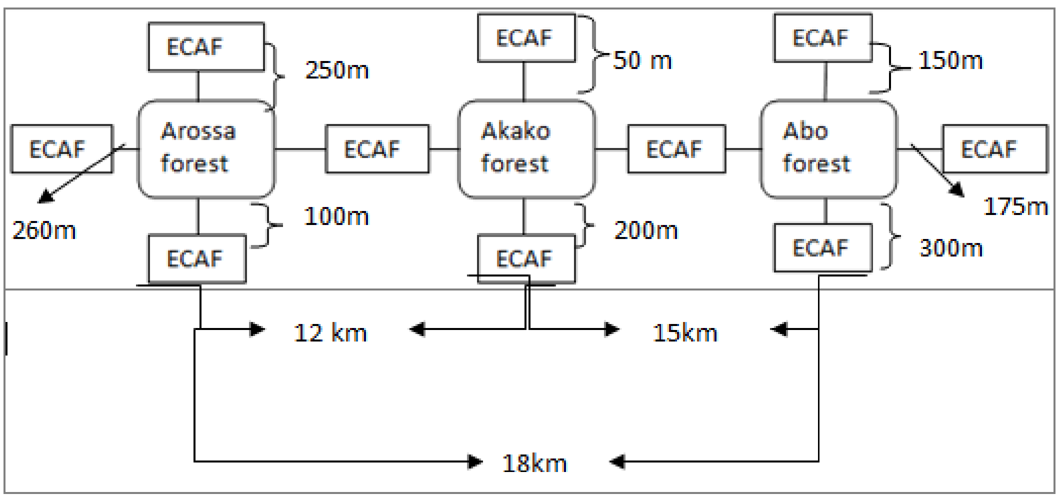

Figure 2. Layout of transect lines for woody species diversity and connectivity study between ECAF and each natural forest patch.

forest patches. On each line E-W and S-N, a serious of quadrats was laid at an interval of 0.5 km in boarder of each forest patch (Figure 2). Hence, 48 quadrats (16 quadrats in each kebele) were established for vegetation assessment for ECAF. To study similarity of woody species compositions managed in ECAF and in the three forest patches, three transect lines was established (Figure 3). On each transect line; four quadrats with intervals of 3 km between quadrat were laid out. A total of 48 quadrats (16 quadrats in each forest patch) were employed for woody species inventory between ECAF and each forest patch.

Sampling design and diversity inventory

For this study, a quadrat size of 20 x 20 m was employed for both ECAF and natural forest patches (Hernandez et al., 2004). Five sub-plots using ''X'' design within the main plots by 5 x 5 m and 2 x 2 m was laid for sapling/shrubs and seedling (<1cm diameter) assessment, respectively (Hernandez et al., 2004). All woody species ≥ 5cm in the main plots were identified and measured using a caliper at breast height (DBH, 1.3 m) (Mac Diken, 1997). Woody species diameters beyond caliper level were measured by measuring tape. Those woody species < 5 cm in sub plots were only identified and counting.

The woody species present in the study area was first identified by their local names in Sidamegna and scientific name was identified using Flora of Ethiopia and Eritrea (Edwards et al., 1995; Hedberg et al., 2004; Hedberg et al., 2006) and “Useful Trees and Shrubs for Ethiopia” (Bekele, 2007).

Data analysis

Woody species diversity and evenness indices in each ECAF and forest patches were calculated by using common alpha diversity indices (Magurran, 2004). Shannon diversity and equitability index

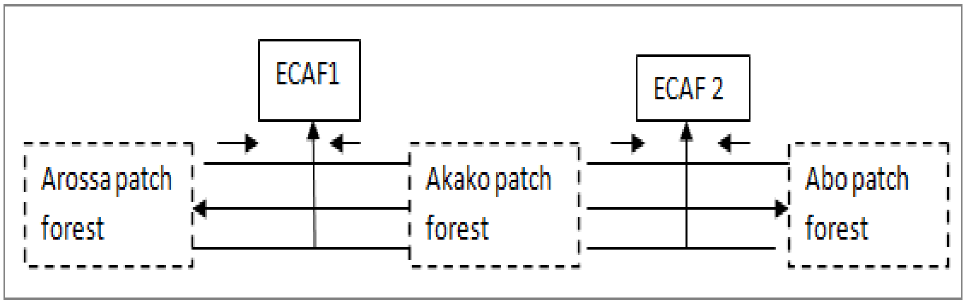

Figure 3. Layout of transect lines for woody species similarity study between the three forest patch and ECAF.ECAF1= Enset-coffee based agroforestry found between Arossa and Akako patch forest; ECAF2=Enset-coffee based agroforestry found between Akako and Abo patch forest.

place most weight on the rare species in the sample ((Magurran, 2004). In order to include the most abundant species, Simpson's diversity index was used. Simpson diversity index gives relatively little weight to the rare species and more weight to the most abundant species. These indices indicate richness and evenness of species within a locality, but they do not indicate the identity of the species where it occurs. Hence, similarity/dissimilarity in composition of woody species among the study forest patches and agroforests was determined by computing Sorensen similarity index. This diversity index takes into account species richness and abundance (Magurran, 2004).

In order to identify the most ecologically importance woody species in study area, importance value index was calculated. The importance value index is a composite index based on the relative measures of species frequency, abundance and dominance (Kent and Coker, 1992). It indicates the significance of species in the system.

The effect of variation in terms of woody species diversity was tested using one way ANOVA and means difference between ECAF and forest patches were considered significant at $p < 0.05$ using least significance difference (LSD).

RESULTS

Floristic composition

A total of 75 woody species were recorded and categorized under 31 families, of which 43 species under 30 families were from the natural forest patches and the remaining 32 species under 21 families from ECAF (Appendix 1 and 2). Twenty two woody species were common to both the natural forest patches and ECAF. Euphorbiaceae and Rutaceae family had the most diverse each having seven and six species, respectively in natural forest patches. Both Myrsinaceae and Araliaceae families each having five species also contributes to the diversity of natural forest patches. Similarly, for ECAF, Euphorbiaceae, Papilioniaceae and Rutaceae families had the most diverse each having three species. The contributions of the remaining families for species richness in ECAF were Asteraceae, Boraginaceae, Cupressaceae, Lauraceae and Myrtaceae with two species. The proportion of indigenous woody species was higher (86.67%) than exotic (13.33%), (Appendix 1 and 2).

Variations were also observed in terms of the relative frequency (Figures 4 and 5). *Cordia africana* (96.7%), *Coffea arabica* (90%), *Millettia ferruginea* (83.3%), *Croton macrostachyus,* (66.7%) and *Persea americana* (63.3%) were the five most frequently found woody species in ECAF (n=48) (Figure 4). From the total 32 woody species, nine species had the lowest frequently found (3.33%) (Figure 4).

Afrocurpus falcatus woody species were 100% frequently found in the study natural forest patches *(n=48) (*Figure 5). *Bersama abyssinica* (96.7%), *Vernonia auriculifera* (83.3%) and *C. macrostachyus* (73.3%) were the other four most frequently found woody species. From the total 43 woody species, 15 species were the lowest frequently found across study natural forest patches (3.3%) (Figure 5).

Woody species diversity

Table 1 shows woody species richness of the each study site. In the natural forest patches, the highest numbers of woody species (richness) were recorded at Abo-Bokaso site and lowest number of species was recorded at Arossa-Garagalo (Table 1). In ECAF, the highest numbers of woody species were found at Akako-Telamo site and lowest number of species was recorded at Arossa-Garagalo (Table 1).

The woody species richness of natural forest patches were significantly ($p<0.05$) higher than ECAF (Table 2). Similarly, there was higher significant ($p<0.05$) variation of woody species abundance per plot in the natural forest patches.

The Shannon diversity index was greater in Abo-Bokaso natural forest patch, and its adjacent ECAF (Table 3). The least Shannon diversity index was recorded in Arossa-Garagalo in both land use type. Shannon evenness (92%) indicates that relatively highest homogeneity of woody species was found in Abo-Bokaso

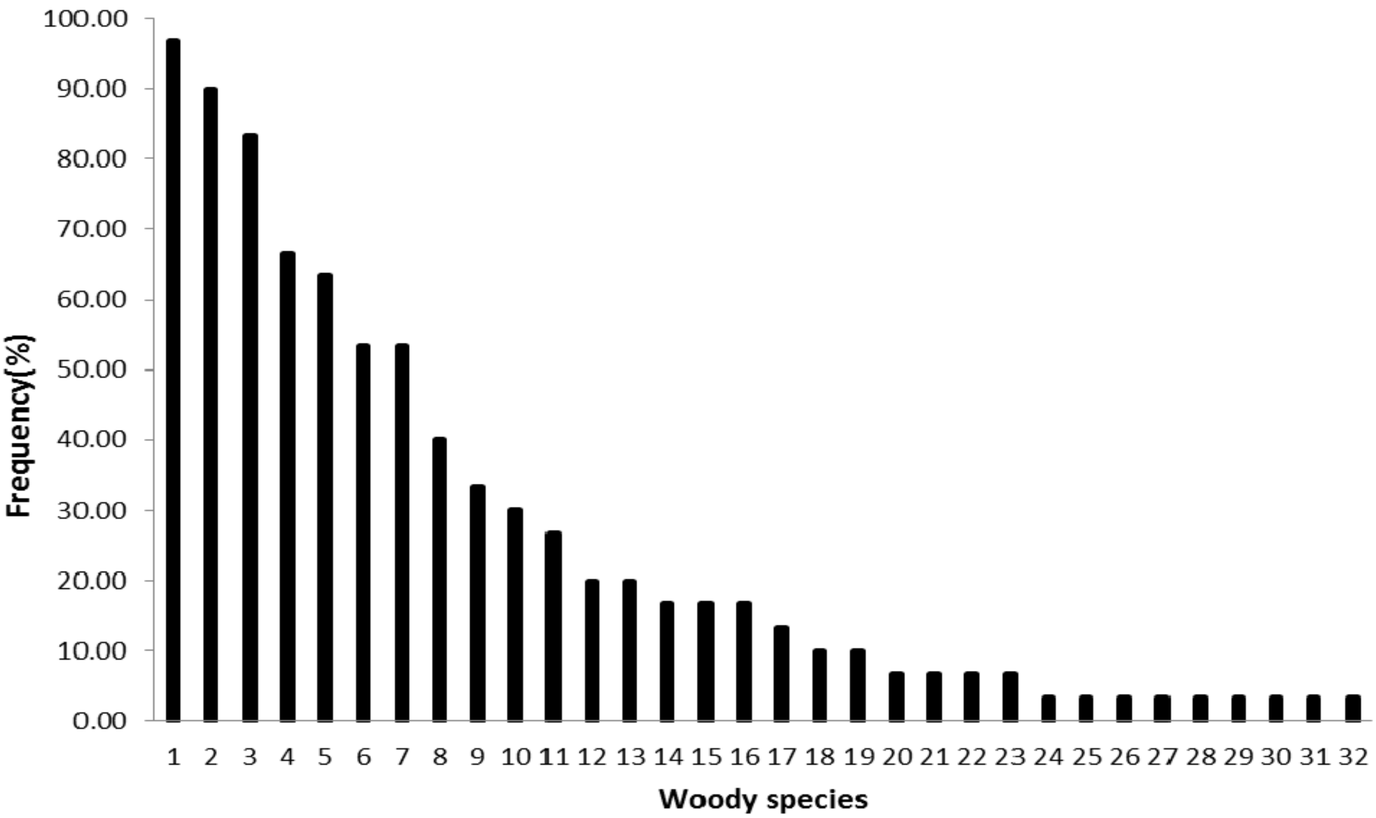

Figure 4. Overall frequency occurrences of woody species across the adjacent ECAF in the midland of Sidama zone, Ethiopia. 1 = *Cordia Africana; 2 = Coffea Arabica;* 3 = *Millettia ferruginea;* 4 = *Croton macrostachyus;* 5 = *Persea Americana;* 6 = *Afrocurpus falcatus;* 7 = *Vernonia auriculifera;* 8 = *Prunus Africana;* 9=*Calpurnia ourea;* 10 = *Fagaropsis angolensis;* 11 = *Bersama abyssinica;* 12= *Syzygium guineense;* 13= *Polyscias fulva;* 14 = *Erythrina brucei;* 15 = *Catha edulis;* 16 = *Maesa lanceolata;* 17 = *Brucea antidysentrica;* 18= *Euphorbia abyssinica;* 19 = *Ficus sur;* 20 = *Casimiora edulis;* 21 = *Ehretia cymosa;* 22 = *Ocotea kenyensis* ; 23 = *Diphasia dainelli;* 24 = *Ricinus communis;* 25 = *Eucalyptus globules;* 26 = *Rhamnus prionoides;* 27 = *Albizia gummifera;* 28 = *Grevillea robusta;* 29=*Cupressus lusitanica;* 30 = *Celtis Africana;* 31 = *Juniperus procera;* 32 = *Vernonia amygdalina.*

natural forest patch compared to other natural forest patches (Table 3). Similarly, the highest evenly distributions of woody species in adjacent ECAF were found in Arossa- Garagalo site (Table 3).

Inland use type comparison, Shannon and Simpson diversity indices of woody species from natural forest patches were significantly ($p < 0.05$) higher than the ones from ECAF (Table 4). However, no significant difference ($P < 0.05$) was observed between the two lands use types in terms of Shannon evenness.

Similarity in woody species compositions of the study land use types

Person's correlation indicated that similarity of woody species of ECAF from each natural forest patch was negatively correlated with distances (Figure 6). This means that when distance increase from the natural forest patch, the similarity of woody species composition between ECAF and natural forest patches was decreased.

Based on presence-absence of woody species in the sampled plot, more than half similarities were existed between overall natural forest patches and ECAF (Table 5). In comparison for each forest patches and their adjacent ECAF, the highest similarity was observed between Arossa-Garagalo natural forest patch and its adjacent ECAF. The least similarity was found between Akako-Telamo natural forest patch and its adjacent ECAF.

The similarity of woody species composition between each three forest patch and adjacent ECAF can be also explained by the presence-absence of species in the land use types (Table 6). Highest similarity of woody species was recorded between Arossa-Garagalo natural forest patch and Akako-Telamo natural forest patch. The Arossa-Garagalo natural forest patch and Abo-Bokaso natural forest patch showed slightly lower similarity. ECAF1 had higher similarity with the nearest Arossa-Garagalo and Akako forest patch, and least similarity with Abo patch. However, ECAF2 was higher similar to Arossa-Garagalo and Akako-Telamo natural forest patch

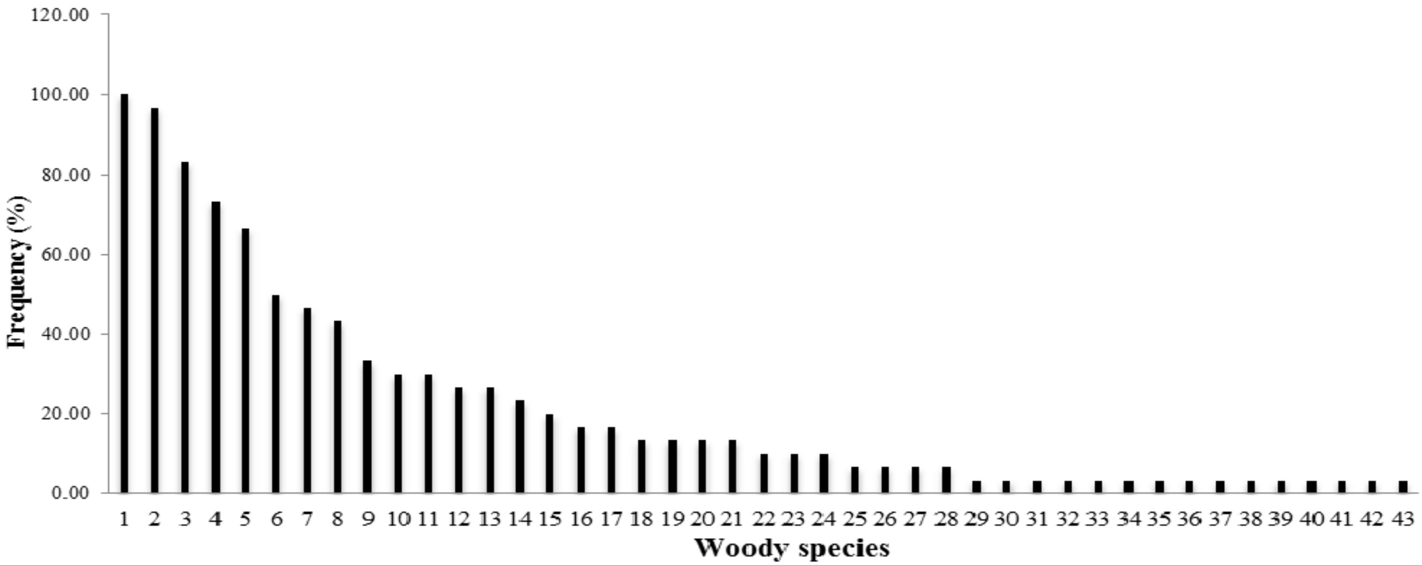

Figure 5.Overall frequency occurrences of woody species across the study natural forest patches in the midland of Sidama zone, Ethiopia.
1 = *Afrocurpus falcatus;* 2 = *Bersama abyssinica;* 3 = *Vernonia auriculifera;* 4 = *Croton macrostachyus;* 5= *Brucea antidysentrica;* 6 = *Calpurnia ourea;* 7 = *Maesa lanceolata;* 8 = *Euphorbia abyssinica;* 9 = *Celtis africana;* 10 = *Acokanthera schimperi;* 11= *Justicia schimperiana; 12 = Fagaropsis angolensis;* 13 = *Polyscias fulva;* 14 = *Ehretia cymosa;* 15 = *Prunus africana;* 16 = *Diphasia dainelli;* 17 = *Olea africana;* 18 = *Syzygium guineense;* 19 = *Celtis kraussiana;* 20 = *Cordia africana;* 21 = *Delonix regia; 22 = Ekbergia capensis;* 23 = *Ricinus communis;* 24 =*Teclea nobilis;* 25 = *Maytenus arbutifolia;* 26 = *Macaranga kilimands;* 27 = *Pouteria adolfi-friedericii;* 28 = *Spathodea nilotica;* 29 = *Juniperus procera;* 30 =*Cupressus lusitanica; 31 = Afrocarpus gracilor;* 32 = *Galiniera saxifrage;* 33 = *Hypericum revoltum;* 34=*Ficus vasta;* 35 = *Phytolaca deodecandra;* 36= *Prunus persica;* 37 =*Albizia gummifera;* 38 = *Agavae sisaliyana;* 39 = *Arundinaria alpina;* 40 = *Ocotea kenyensis;* 41 = *Ficus sur;*42 = *Dodonaea viscosa;* 43 = *Lepidotrichilia volkensii.*

Table 1. Woody species richness in each natural forest patch and adjacent ECAF in the midland of Sidama zone, Ethiopia.

Forest/site name	Number of species (richness) in	
	Patch forest	ECAF
Akako-Telamo	20	27
Arossa-Garagalo	17	15
Abo- Bokaso	31	17
Overall richness	43	32

Table 2. Mean (±std) woody species richness and abundance per plot of the two land use types.

Land use type	Richness	Abundance
	Mean(±std)	Mean(±std)
ECAF	8.2^{a}±0.413	79.3^{a}±7.291
Natural forest Patches	9.6^{b}±0.188	128.5^{b}±9.281
Overall mean	8.9±3.099	103.9±16.551

Means followed by a different superscript (a, b) are significantly different at LSD (p< 0.05.

Table 3. Woody species diversity in each vegetation patches and adjacent ECAF in the midland of Sidama zone, Ethiopia.

Forest/site name	Woody species diversity in					
	Patch forest			ECAF		
	Shannon	Simpson	Evenness	Shannon	Simpson	Evenness
Akako-Telamo	2.70	0.96	0.86	2.31	0.96	0.86
Arossa-Garagalo	2.61	0.98	0.80	2.21	0.97	0.89
Abo- Bokaso	2.75	0.9	0.92	2.41	0.96	0.61

Table 4. Mean (±std) woody species diversity index of Shannon, Evenness and Simpson per plot of the two land use type.

Land use type	Shannon	Simpson	Evenness
	Mean (±std)	Mean (±std)	Mean (±std
ECAF	1.55[a] ±0.033	0.71[a]±0.017	0.76[a] ±0.02
Natural forest Patches	1.81[b]±0.054	0.79[b]±0.001	0.8[a] ±0.01
Overall mean	1.68±0.058	0.75±0.005	0.78±0.02

Means followed by a different superscript (a, b) are significantly different at LSD (p< 0.05).

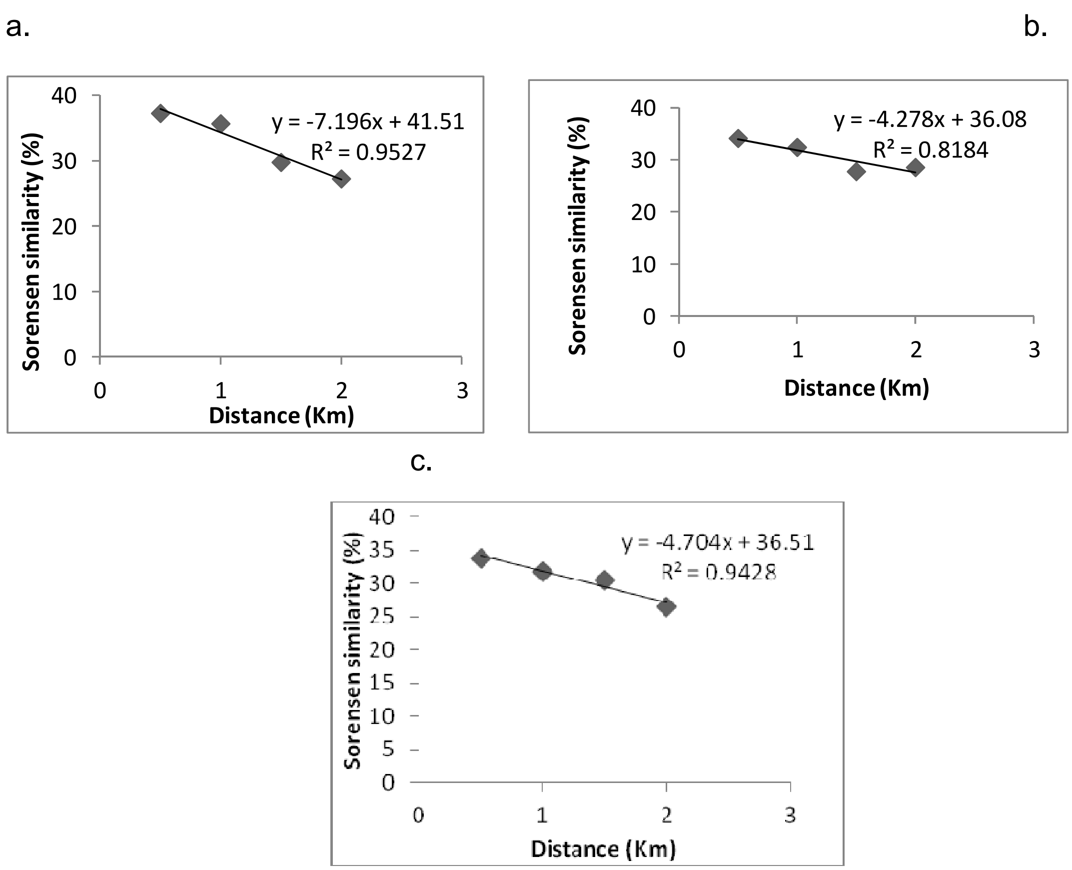

Figure 6. Correlation between the Sorensen similarity (%) of woody species and distance of ECAF from each natural forest patch. **a.** At Akako natural patch forest; **b.** At Arossa natural forest patch; **c.** At Abo natural forest patch.

Table 5. Sorensen's similarity index of woody species between each vegetation patches and adjacent ECAF in the midland of Sidama zone, Ethiopia .

Forest/site name	Sorensen's similarity index (%) With adjacent ECAF
Arossa-Garagalo	56.25
Akako-Telamo	48.89
Abo- Bokaso	50
Overall similarity of patch forests	58.67

Table 6. The mean Sorensen's similarity index of woody species between each vegetation patches and ECAF in the midland of Sidama zone, Ethiopia.

Land use/site name	Sorensen's similarity index (%) land use/site name				
	Arossa-Garagalo	ECAF1	Akako-Telamo	ECAF2	Abo-Bokaso
Arossa-Garagalo		46.4	54.1	46.6	41.7
ECAF1			47.9	55.4	32.34
Akako-Telamo				46.9	50.9
ECAF2					38.4
Abo-Bokaso					

ECAF1= Enset-coffee based agroforestry found between Arossa and Akako forest patch; ECAF2= Enset-coffee based agroforestry found between Akako and Abo forest patch.

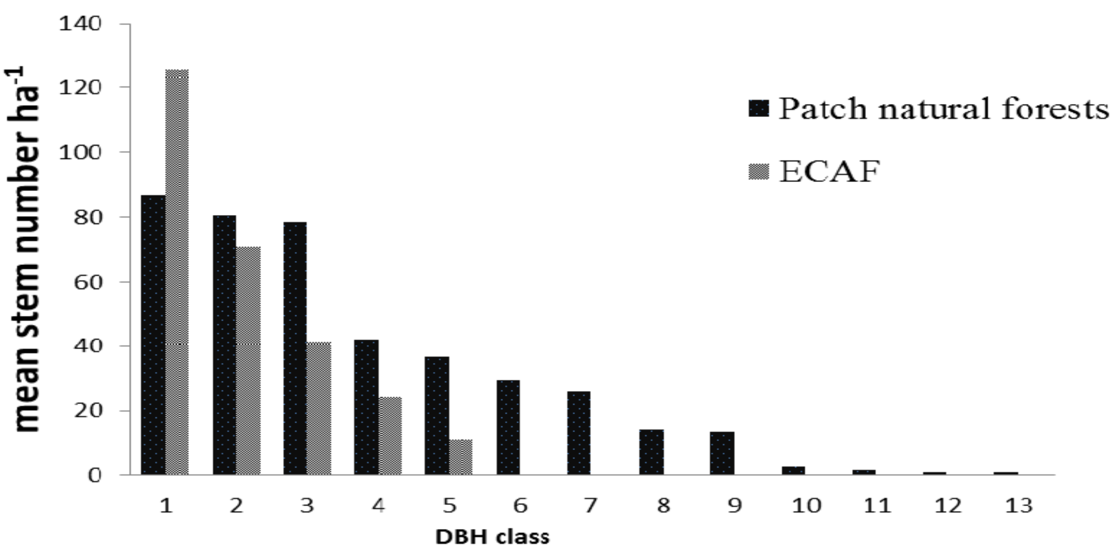

Figure 7. Cumulative frequency distributions of woody species by diameter class in overall Natural forest patches and ECAF in the midland of Sidama. Diameter class in cm **1=** 5-15, **2=** >15-25, **3=** >25-35, **4=** >35-45, **5=** >45-55, **6=** >55-65, **7=** >65-75, **8=** >75-85, **9=** >85-95, **10=** >95-105, **11=** >105-115, **12=** >115-125, **13=** >125.

and least similarity with the Abo-Bokaso forest patch. More than 50% of woody species similarity was found in ECAF1 and ECAF2.

The similarity of woody species composition in each forest patch and ECAF along transect distance was indicated in an Appendix 5. The highest similarity of woody species in ECAF was found near to the natural forest patches in all types of forest patch at referencing point (0.5 km) (Appendix 5).

Community structure of woody species

Community structure of woody species in the natural forest patches and ECAF in terms of mean numbers of

Table 7. The top five most IVI of woody species in a decreasing order in natural forest patches and ECAF in the midland of Sidama, Ethiopia.

Land use type	Scientific name	Important value index (IVI in %)
Natural forest patches	*Afrocurpus falcatus*	78.9
	Vernonia rueppllii	24.1
	Bersama abyssinica	22.2
	Calpurnia ourea	21.0
	Celtis africana	16.8
ECAF	*Coffea arabica*	65.8
	Cordia africana	47.5
	Millettia ferruginea	22.7
	Croton macrostachyus	19.3
	Persea americana	18.9

trees in diameter classes are presented in Figure 7.

Although the young individuals belonging to 5-15 cm DBH class were dominating in both land use systems, the number of stems (≥ 5cm DBH) were greater in natural forest patches than ECAF plots. In the natural forest patches, the 79% of the total tree density was distributed between 5 to 45 cm diameter classes. However, in ECAF, 72% of the total tree density was distributed between 5 and 25 cm. Generally, the cumulative diameter class distribution pattern was an inverted J-shape, which showed that the species frequency was highest in the lower diameter classes and decreased gradually towards the higher classes.

Importance value index of woody species

The importance value index (IVI) measures the overall importance of a species and gives an indication of the ecological success of a species in a particular area. The IVI of all woody species in each land use type was indicated in Appendix 3 and 4. The five most important woody species with the highest IVIs in the natural forest patches and ECAF in decreasing order is given in Table 7. *A. falcatus* followed by *V. rueppllii* was the highest IVI in natural forest patches, and *C. arabica* and *C. africana* was in the ECAF (Table 7).

DISCUSSION

Woody species composition and diversity

Our results indicate that for ECAF in the study sites, the total woody species richness number was comparatively lower than that recorded in enset-coffee-based agroforests (58 woody of species) and tree-cereal-based agroforestry systems (64 woody species) of the south-central and southern highlands of Ethiopia, respectively (Negash et al., 2012b; Asfaw, 2003). In previous studies (Asfaw 2003; Tolera et al., 2008), total number of all woody individuals vary, which might be due to the comparatively limited number of stems. For example, Gedeo multistrata agroforestry system is characterized by both horizontally and vertically densely packed agroforestry systems (Tesemma, 2007). ECAF at our study sites had four strata (Negash et al., 2012b). The variation may be ecological, demographic, farm size, the physical condition of the site and socioeconomic factors of the area. Variation in mean number of species richness and abundance was also shown among agroforest types. Farmers in enset-AF give more emphasis to managing and cultivating *E. ventricosum* with native woody species (Negash et al., 2012b). They practice thinning to create more space for production of *E. ventricosum*. Wider spacing of trees would allow more growth in tree diameter rather than in stem numbers in enset-AF.

The total woody species recorded in the natural forest patches was also comparable to earlier studies in Ghana (47) natural forests (Amoha, 2011), but higher than Tanzania (29) (Rocky and Mligo, 2012). Woody species richness and abundance in natural forest patches were significantly higher than ECAF is consistent with other study in India and Gahana (Amoha, 2011, Tynsong and Tiwari, 2011). High species richness and abundance could be due to relatively minimum disturbance by the people over a long period in forest patches, and species preferences in ECAF system.

The overall Shannon's diversity and evenness in study ECAF were 2.31 and 0.79 respectively. According to Kent and Coker (1992), the Shannon-Weiner diversity index normally varies between 1.5 and 3.5 and rarely exceeds 4.5. In our study of ECAF and natural forest patches, the diversity indices and evenness were in line with the stated ranges. It was also comparable with the studies from north- western homegardens of Ethiopia (H'=3.34) (Mekonnin et al, 2014). However, it was comparatively higher than that was in enset-coffee-based agroforests (H'=1.07), Sidama homegardens, (H'= 1.44) of the south-central and southern highlands of Ethiopia, (respectively (Negash et al., 2012b; Abebe, 2005) but lower than homegarden of Meghalaya (H'=2.37) (Tynsong and Tiwari, 2010). The variation perhaps depends on differences in farmers' management intensity, and on environmental conditions. Farmers' shade intensity management includes species selection, setting spacing, pollarding, lopping and thinning (Negash et al., 2012b; Abebe, 2005).

Shannon's diversity index (2.61) in natural forest patches agrees with Harenna forest (H'=2.60), but higher than maji forest (H'=1.54) (Senbeta, 2006). Higher diversity index in natural forest patches than ECAF was comparable with Ghana natural forests and taungya agroforestry (Amoha, 2011). This could be the uniform distribution of species in natural forests, site characteristics and enriched by the farmers with economically important tree species that meet the needs of the local people in ECAF.

The frequent occurrence of the most valuable woody species was estimated to know the extent of species distribution in study areas. Our results also show that *C. Africana* (96.7%), *C. arabica* (90%) and *M*. *ferruginea* (83.3%) were the highest frequently occurring tree species in studies of ECAF. *M*. *ferruginea* in particular was the most abundant and frequent native species across all study ECAF sites. This is mainly due to the easy adaptability, propagation and management regime of the species (Negash et al., 2012b; Abebe, 2005). A study carried out in southern Ethiopia also showed that the Millettia tree increased the productivity of crops planted beneath it, due to frequent planting in and the in the border of the farm lands (Hailu et al., 2000). In addition, In ECAF, both *C. africana* and M. ferruginea recommended as coffee and enset shade. Similar studies were observed in southern and eastern Ethiopia (Teketay and Tegineh, 1991; Abebe, 2005; Negash et al., 2012b). The most frequently found of this species, particularly *M. ferruginea* and *C. arabica* only found in ECAF were due to the complimentary to agricultural crops and being provider of multiple benefits to the societies (Abebe, 2005).

The importance value index (IVI) rank species in a way as to give an indication on which species come out as important component of the on-farm trees (Munishi et al., 2008). It measures the overall importance of a species and gives an indication of the ecological success of a species in a particular area. The most important tree species which is the highest IVI recorded in ECAF system agrees with the study by Abebe (2005) that reported tree species with highest importance value indices.

The most important tree species in the natural forest patches were *A. falcatus*, *V. rueppllii*, *B*. *abyssinica*, *C. ourea* and *C. africana*. They are common and abundant because of their wide economic and ecological roles in the systems. The IVI values can also be used to prioritize species for conservation, and species with high IVI value need less conservation efforts, whereas, those having low IVI value need high conservation effort.

The overall community structure of the patch forests and ECAF can help understand the status of regeneration. Reverse J-shaped distributions indicated more or less a healthy or stable regeneration (Tesfaye et al., 2010; Worku et al., 2012). This means high numbers of individuals (juvenile/seedling) in the lower diameter classes but decreases towards the higher classes. The observation of juvenile/seedling phase of these woody species is an evidence of dynamics in managing biodiversity in the land uses.

Similarity of woody species and implication to agriculture landscape connectivity

Agroforest land use can provide potential sites for maintaining both species in agricultural landscapes. The increased incorporation of woody species in agroforestry land can reduce pressure on forests and protected conservation areas. The result of present study indicate that woody species recorded from ECAF constitutes larger proportion of indigenous species (84.6%), which may be a reflection of the conservation of biodiversity in the agricultural landscapes. Similar trend were observed by other scholars (Abebe, 2005) for 83% indigenous tree species. Asfaw (2003) reported about 68 to 80% indigenous tree species for different sites in the traditional agroforestry practices of Sidama, Ethiopia.

Our results also indicate that 58.67% of woody species composition similarity existed between natural forest patches and ECAF. Such overlap of woody species indicated that development of buffer zone agroforestry adjacent to the natural forest would help to provide different uses and services, which were being obtained from natural forest by the local community and thus bring down the dependency on the natural forests and take as conservation strategy for threatened forest resource (Worku, 2011; Kasolo & Temu, 2008). ECAF can also serve as gene pools for the eroding indigenous woody species. Many indigenous, rare woody species like Cordia africana, Croton macrostachys and Afrocarpus falcate conserved in ECAF because of their high multiple values. This finding was supported by Gebremariam et al. (2009); they reported that *C. africana* and *P*. *falcatus* are accounted as locally endangered species, and are not legally permitted to be felled in state and private forests, owing to their high exploitation in natural forests in Ethiopia. Agroforestry can also create habitat for wild animal species in landscape matrices surrounding forest conservation areas (Buck et al., 2004). Therefore, the integration of woody species in the homegardens adds plant and animal biodiversity into landscapes that might otherwise contain only monocultures of agricultural crops (Guo, 2000).

Conclusion

The ECAF and natural forest patches in our studies constitutes larger proportion of indigenous woody species which may be a reflection of the conservation of biodiversity in the agricultural landscapes. This is possibly due to farmers' management practice in maintaining more native trees for shading both coffee and enset particularly in ECAF. In addition, ECAF play a major role in the conservation of native woody species like *Syzygium guineense* and *Juniperus procea* which are endemic in Ethiopia, and the critically threated species like *Pouteria adolfi-friedericii* and *prunus Africana.* Our study shows that ECAF are also important for preserving the most economical value trees such as *C. africana, Croton macrostachys* and *Afrocarpus falcate* which uses as shade of coffee and enset.

Our study also indicated a higher similarity of woody species composition between ECAF and natural forest patches. This may reduce the dependency of local communities on forest patches due to ECAF and provides different uses and services which can be obtained from natural forest patches.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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Appendix

Appendix 1. The botanical name of woody species in the overall natural forest patches in Shebedino and Wonsho district in the midland of Sidama zone, Ethiopia.

No.	***Botanical name***	**Local name**	**Origin**	**Family**
1.	*Acokanthera schimperi* (D.C., Oliv)	Qararu	Indigenous	Apocynaceae
2.	*Afrocurpus falcatus (*Thunb.)**	Dagucho	Indigenous	Podocarpaceae
3.	*Afrcarpus gracilor* (Oliv.& hiern)	Danishicho	Indigenous	Podocarpaceae
4.	*Agavae sisaliyana* (Perr)	Qacha	Exotic	Agavaceae
5.	*Albizia gummifera* (G.F.Gmel..C.A.Sm.)	Maticho	Indigenous	Mimosaceae
6.	*Arundinaria alpina* (K.Schum)	Lemicho	Indigenous	Bambusaceae
7.	*Bersama abyssinica* (Fres)	Xabaraco	Indigenous	Melianthaceae
8.	*Brucea antidysentrica* (J.F.Miller)	Haxawicho	Indigenous	Simaroubaceae
9.	*Calpurnia ourea (*Lam., benth)	Chekata	Indigenous	Papilioniaceae
10.	*Celtis africana (*Burm.F.)	Shisho	Indigenous	Ulmaceae
11.	*Celtis kraussiana* (Bernh)	sheshie	Indigenous	Ulmaceae
12.	*Cordia africana* (Lam)	Wadicho	Indigenous	Boraginaceae
13.	*Croton macrostachyus* (Hochst. Ex. Del.)	Macincho	Indigenous	Euphorbiaceae
14.	*Cupressus lusitanica* (Mill.)	Homme	Exotic	Cupressaceae
15.	*Delonix regia (*Bojer Ex Hook. Raf)	*yederdawa zafe	Exotic	Caesinalpiodeae
16.	*Diphasia dainelli* (Pichi-Sem.)	Lelcho	Indigenous	Rutaceae
17.	*Dodonaea viscosa* (L.F.)	Itancha	Indigenous	Sapindaceae
18.	*Ehretia cymosa* (Thonn.)	Gidincho	Indigenous	Boraginaceae
19.	*Ekbergia capensis* (Sparrman)	Oloncho	Indigenous	Meliaceae
20.	*Euphorbia abyssinica (*Gmel.)	Carricho	Indigenous	Euphorbiaceae

Appendix 1. Contd.

No.	*Botanical name*	Local name	Origin	Family
21.	*Fagaropsis angolensis (*Engl.Del.)	Goddicho	Indigenous	Rutaceae
22.	*Ficus sur (*Forssk.)	Oddako	Indigenous	Moraceae
23.	*Ficus vasta (*Forssk)	*Warka	Indigenous	Moraceae
24.	*Galiniera saxifrage* (E.Mey.Ex Benth)	Dongicho	Indigenous	Icacinaceae
25.	*Hypericum revoltum (*Vahl)	Garambicho	Indigenous	Hypericaceae
26.	*Juniperus procera* (Hochst.Ex. Endl.)	Honcho	Indigenous	Cupressaceae
27.	*Justicia schimperiana* (Hochst.ex Nees)	Cheketa	Indigenous	Acanthaceae
28.	*Lepidotrichilia volkensii (*Gurke, Leroy)	Tontoloma	Indigenous	Meliaceae
29.	*Macaranga kilimands* (Pax)	Felleco	Indigenous	Euphorbiaceae
30.	*Maesa lanceolata (*Forssk)	Gobacho	Indigenous	Myrsinaceae
31.	*Maytenus arbutifolia* (A.Rich,Wilczeck)	Cucco/atata	Indigenous	Celastraceae
32.	*Ocotea kenyensis (*Kosterm).	Shoecho	Indigenous	Lauraceae
33.	*Olea africana* (Mill*)*	Ejersu	Indigenous	Oleaceae
34.	*Phytolaca deodecandra* (L'Herit)	Haraje	Indigenous	Phytolacaceae
35.	*Polyscias fulva* (Hiern,Harms)	Kobree	Indigenous	Araliaceae
36.	*Pouteria adolfi -friedericii (*A..Chev,Aubrev & Pellegr)**	Dugucho	Indigenous	Sapotaceae
37.	*Prunus africana (*Hook.f. Kalkm)	Garbich	Indigenous	Rosaceae
38.	*Prunus persica (*L. Batsch*)*	Koke	Exotic	Rosaceae
39.	*Ricinus communis* (L.)	Qenbo	Indigenous	Euphorbiaceae
40.	*Syzygium guineense* (Wild.D.C*)*	Duwancho	Indigenous	Myrtaceae
41.	*Spathodea nilotica* (Seem)	*ychaka nebelbal	Exotic	Bignoniaceae
42.	*Teclea nobilis* (Del.)	Haddessa	Indigenous	Rutaceae
43.	*Vernonia auriculifera* (Hiern)	Rejicho	Indigenous	Asteraceae

*= Amharic name, all others Sidamegna name, **= the current name of *Podocarpus falcatus* and *Aningeria adolfi -friedericii.*

Appendix 2. The botanical names of woody species in enset-coffee based agroforestry in Shebedino and Wonsho district in the midland of Sidama zone, Ethiopia.

No.	*Botanical name*	Local name	Origin	Family
1.	*Afrocurpus falcatus (*Thunb.)	Dagucho	Indigenous	Podocarpaceae
2.	*Albizia gummifera (*G.F.Gmel.,.C.A.Sm.)	Maticho	Indigenous	Mimosaceae
3.	*Bersama abyssinica (*Fres.)	Xabaraco	Indigenous	Melianthaceae
4.	*Brucea antidysentrica* (J.F.Miller)	Haxawicho	Indigenous	Simaroubaceae
5.	*Calpurnia ourea* (Lam. benth)	Chekata	Indigenous	Papilioniaceae
6.	*Casimiora edulis* (La L,lave & Lex.)	Kasmire	Exotic	Rutaceae
7.	*Chata edulis* (Vahl. ,Forssk.ex Endl.)	Chate	Indigenous	Celastraceae
8.	*Celtis africana (*Burm.F.)	Shisho	Indigenous	Ulmaceae
9.	*Coffee arabica (*L.)	Bunu	Indigenous	Rubiaceae
10.	*Cordia africana* (Lam.)	Wadicho	Indigenous	Boraginaceae
11.	*Croton macrostachys (*Hochst. Ex Del.)	Macincho	Indigenous	Euphorbiaceae
12.	*Cupressus lusitanica* (Mill)	Homme	Exotic	Cupressaceae
13.	*Diphasia dainelli (*Pichi-Sem*.)*	Lelcho	Indigenous	Rutaceae
14.	*Ehretia cymosa (*T.honn)	Gidincho	Indigenous	Boraginaceae
15.	*Erythrina brucei* (schweinf)	Wellako	Indigenous	Papilonaceae
16.	*Eucalyptus globulus (*Labill.)	Waju arzafe	Exotic	Myrtaceae
17.	*Euphorbia abyssinica (*Gmel.)	Carricho	Indigenous	Euphorbiaceae
18.	*Fagaropsis angolensis (*Engl., Del.)	Goddicho	Indigenous	Rutaceae
19.	*Ficus sur (*Forssk.)	Oddako	Indigenous	Moraceae
20.	*Grevillea robusta (*A.Cunn.Ex.R.Br.)	Geravela	Exotic	Proteaceae

Appendix 2. Contd.

No.	Botanical name	Local name	Origin	Family
21.	*Juniperus procera (*Hochst.Ex. Endl.)	Honcho	Indigenous	Cupressaceae
22.	*Maesa lanceolata* (Forssk)	Gobacho	Indigenous	Myrsinaceae
23.	*Millettia ferruginea* (Hochyst, Baker)	Hengedicho	Indigenous	Papilionoideae
24.	*Ocotea kenyensis* (Kosterm)	Shoecho	Indigenous	Lauraceae
25.	*Persea americana* (Mill)	Abukato	Exotic	Lauraceae
26.	*Polyscias fulva* (Hiern, Harms)	Kobree	Indigenous	Araliaceae
27.	*Prunus africana* (Hook.f., Kalkm)	Garbicho	Indigenous	Rosaceae
28.	*Rhamnus prionoides* (L.'Herit.)	Taddo	Indigenous	Rhamnaceae
29.	*Ricinus communis* (L)	Qenbo	Indigenous	Euphorbiaceae
30.	*Syzygium guineense (*Wild., DC.)	Duwancho	Indigenous	Myrtaceae
31.	*Vernonia amygdalina* (Del.)	Hecho	Indigenous	Asteraceae
32.	*Vernonia auriculifera* (Hiern)	Rejicho	Indigenous	Asteraceae

Appendix 3. List of Frequency (FR), Abundance (AD), Relative frequency (RF), Relative abundance (RA), Relative dominance (RD) and Importance Value Indices (IVI) of woody species in the overall study natural forest patches.

No.	Botanical name	Frequency	Abundance	RD%	RA%	RF%	IVI%
1.	*Acokanthera schimperi*	9	143	0.00	3.83	3.18	7.01
2	*Afrocurpus falcatus*	30	675	50.23	18.06	10.60	78.89
3.	*Afrocarpus gracilor*	1	4	0.00	0.11	0.35	0.46
4.	*Agavae sisaliyana*	1	8	0.01	0.21	0.35	0.58
5.	*Albizzia gummifera*	1	10	0.00	0.27	0.35	0.62
6.	*Arundinaria alpina*	1	5	0.00	0.13	0.35	0.49
7.	*Bersama abyssinica*	29	398	1.29	10.65	10.25	22.19
8.	*Brucea antidysentrica*	20	304	0.00	8.13	7.07	15.20
9.	*Calpurnia ourea*	15	575	0.33	15.39	5.30	21.02
10.	*Celtis africana*	10	88	10.92	2.35	3.53	16.80
11.	*Celtis kraussiana*	4	43	0.00	1.15	1.41	2.56
12.	*Cordia africana*	4	16	0.44	0.43	1.41	2.28
13.	*Croton macrostachys*	22	126	5.03	3.37	7.77	16.18
14.	*Cupressus lusitanica*	1	2	0.00	0.05	0.35	0.41
15.	*Delonix regia*	4	36	0.36	0.96	1.41	2.73
16.	*Diphasia dainelli*	5	15	0.36	0.40	1.77	2.53
17.	*Dodonaea viscosa*	1	1	0.00	0.03	0.35	0.38
18.	*Ehretia cymosa*	7	12	0.32	0.32	2.47	3.11
19.	*Ekbergia capensis*	3	6	0.00	0.16	1.06	1.22
20.	*Euphorbia abyssinica*	13	35	4.76	0.94	4.59	10.29
21.	*Fagaropsis angolensis*	8	71	5.58	1.90	2.83	10.31
22.	*Ficus sur*	1	2	0.38	0.05	0.35	0.79
23.	*Ficus vasta*	1	12	0.00	0.32	0.35	0.67
24.	*Galiniera saxifrage*	1	6	0.45	0.16	0.35	0.96
25.	*Hypericum revoltum*	1	2	0.47	0.05	0.35	0.87
26.	*Juniperus procera*	1	2	0.00	0.05	0.35	0.41
27.	*Justicia schimperiana*	9	297	0.00	7.95	3.18	11.13
28.	*Lepidotrichilia volkensii*	1	1	0.00	0.03	0.35	0.38
29.	*Macaranga kilimands*	2	15	0.06	0.40	0.71	1.17
30.	*Maesa lanceolata*	14	54	2.59	1.45	4.95	8.98
31.	*Maytenus arbutifolia*	2	13	0.00	0.35	0.71	1.05

Appendix 3. Contd.

No.	Botanical name	Frequency	Abundance	RD%	RA%	RF%	IVI%
32.	*Ocotea kenyensis*	1	7	0.00	0.19	0.35	0.54
33.	*Olea africana*	5	24	0.00	0.64	1.77	2.41
34.	*Phytolaca deodecandra*	1	15	0.58	0.40	0.35	1.33
35.	*Polyscias fulva*	8	18	2.09	0.48	2.83	5.40
36.	*Pouteria adolfi -friedericii*	2	5	5.99	0.13	0.71	6.83
37.	*Prunus africana*	6	6	0.94	0.16	2.12	3.22
38.	*Prunus persica*	1	2	0.01	0.05	0.35	0.42
39.	*Ricinus communis*	3	56	0.00	1.50	1.06	2.56
40.	*Syzygium guineense*	4	11	5.07	0.29	1.41	6.77
41.	*Spathodea nilotica*	2	30	1.47	0.80	0.71	2.98
42.	*Teclea nobilis*	3	28	0.00	0.75	1.06	1.81
43.	*Vernonia auriculifera*	25	555	0.29	14.93	8.83	24.06

Appendix 4. List of frequency (FR), abundance (AD), relative frequency (RF), relative abundance (RA), relative dominance (RD) and Importance value Indices (IVI) of woody species in the ECAF in the midland of Sidama.

No.	Botanical name	Abundance	Frequency	RD %	RA%	RF%	IVI %
1.	*Afrocurpus falcatus*	11	12.00	5.61	0.45	4.90	10.96
2.	*Albizia gummifera*	1	1.00	0.11	0.03	0.41	0.55
3.	*Bersama abyssinica*	28	8.00	0.63	1.18	3.27	5.08
4.	*Brucea antidysentrica*	13	4.00	0.00	0.52	1.63	2.15
5.	*Calpurnia ourea*	69	10.00	0.00	2.88	4.08	6.97
6.	*Casimiora edulis*	5	2.00	0.00	0.21	0.82	1.02
7.	*Catha edulis*	142	5.00	0.00	5.91	2.04	7.95
8.	*Celtis africana*	4	1.00	0.31	0.17	0.41	0.89
9.	*Coffee arabica*	1267	27.00	1.05	53.75	11.02	65.83
10.	*Cordia africana*	220	29.00	26.45	9.17	11.84	47.46
11.	*Croton macrostachys*	53	20.00	8.90	2.19	8.16	19.25
12.	*Cupressus lusitanica*	3	1.00	0.00	0.10	0.41	0.51
13.	*Diphasia dainelli*	9	5.00	4.30	0.38	2.04	6.73
14.	*Ehretia cymosa*	1	1.00	0.04	0.03	0.41	0.48
15.	*Erythrina brucei*	3	3.00	1.52	0.14	1.22	2.88
16.	*Eucalyptus globulus*	4	3.00	4.41	0.17	1.22	5.80
17.	*Euphorbia abyssinica*	7	2.00	0.00	0.28	0.82	1.09
18.	*Fagaropsis angolensis*	32	9.00	1.02	1.32	3.67	6.01
19.	*Ficus sur*	7	5.00	3.03	0.28	2.04	5.35
20.	*Grevillea robusta*	2	1.00	0.00	0.07	0.41	0.48
21.	*Juniperus procera*	2	2.00	0.19	0.07	0.82	1.07
22.	*Maesa lanceolata*	67	1.00	0.59	2.78	0.41	3.78
23.	*Milletia ferruginea*	144	25.00	6.49	6.01	10.20	22.71
24.	*Ocotea kenyensis*	75	19.00	8.05	3.13	7.76	18.93
25.	*Persea americana*	73	16.00	0.00	3.06	6.53	9.59
26.	*Polyscias fulva*	1	1.00	0.00	0.03	0.41	0.44
27.	*Prunus africana*	1	1.00	0.01	0.03	0.41	0.46
28.	*Rhamnus prionoides*	4	2.00	0.10	0.17	0.82	1.09
29.	*Ricinus communis*	15	6.00	4.93	0.63	2.45	8.00
30.	*Syzygium guineense*	7	6.00	5.40	0.28	2.45	8.13
31.	*Vernonia amygdalina*	1	1.00	0.09	0.03	0.41	0.54
32.	*Vernonia auriculifera*	108	16.00	0.49	4.52	6.53	11.53

Appendix 5. The mean Sorensen's similarity index (%) of woody species at each natural forest patch and between ECAF in the midland of Sidama zone, Ethiopia.

	Sorensen's similarity index (%) of woody species																		
		Enset-coffee based agroforestry(ECAF1)									Enset-coffee based agroforestry(ECAF2)								
	Arossa F	**A1**	**A2**	**A3**	**A4**	**B5**	**B6**	**B7**	**B8**	**Akako.F**	**B9**	**B10**	**B11**	**B12**	**C13**	**C14**	**C15**	**C16**	**Abo.F**
Arossa forest		57.1	46.2	48.0	44.4	55.2	44.4	37.0	38.5	54.1	41.7	46.2	46.2	48.3	40.0	51.6	51.9	46.7	41.7
A1 (at 0.5km)from Arossa			66.7	48.0	72.7	91.7	54.5	45.5	57.1	56.3	52.6	66.7	76.2	75.0	64.0	69.2	81.8	64.0	37.2
A2 (at 3 km)from Arossa				47.1	52.6	66.7	52.6	21.1	77.8	50.0	25.0	55.6	44.4	57.1	45.5	52.2	42.1	45.5	35.0
A3(at 6km) from Arossa					55.6	70.0	55.6	33.3	47.1	35.7	53.3	58.8	70.6	60.0	57.1	72.7	66.7	76.2	30.8
A4 (at 9km) from Arossa						63.6	40.0	20.0	31.6	42.9	23.5	42.1	52.6	72.7	52.2	66.7	60.0	52.2	29.3
B5 (at 9km)from Akako							63.6	45.5	57.1	53.3	52.6	66.7	66.7	75.0	72.0	69.2	72.7	72.0	27.9
B6(at 6km) from Akako								42.9	52.6	50.0	35.3	73.7	63.2	37.0	60.9	50.0	70.0	63.6	34.1
B7(at 3km) from Akako									31.6	48.6	58.8	42.1	42.1	36.4	34.8	33.3	40.0	36.4	24.4
B8(at 0.5km) from Akako										46.7	33.3	44.4	44.4	57.1	45.5	52.2	47.1	45.5	40.0
Akako forest											56.3	55.2	41.4	29.6	42.4	52.9	46.7	48.5	51.0
B9(0.5km) from Akako												35.3	50.0	42.1	50.0	47.6	58.8	57.1	26.3
B10(at 3km)from Akako													55.6	57.1	54.5	43.5	63.2	54.5	30.0
B11(at 6km) from Akako														66.7	63.6	69.6	73.7	63.6	35.0
B12(at 9km) from Akako															56.0	69.2	63.6	56.0	37.2
C13(at 9km) from Abo																81.5	78.3	76.9	45.5
C14(at 6km) from Abo																	78.3	81.5	39.0
C15(at 3km) from Abo																		81.8	40.9
C16(0.5km)from Abo																			53.3
Abo forest																			

A1, A2………………C16 stands for number of quadrats; A1-----A4 quadrats has taken from Arossa patch forest towards Akako patch forest in ECAF1 land use; B8-----B5 quadrats have taken from Akako patch forest towards Arossa forest in ECAF1 land use; B9---B12 quadrats has taken from Akako patch forest towards Abo patch forest in ECAF2 land use. C16—C13 quadrats have taken from Abo patch forest towards Akako patch forest in ECAF2 land use. Sorensen's similarity of woody species at each forest and quadrats taken from ECAF land use were calculated.