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Effect of Forest Coffee Management Practices on Woody Species Diversity and Composition in Bale Eco-Region, Southeastern Ethiopia

Gonfa Kewessa[1*], Lemma Tiki[2], Dejene Nigatu[3], Demeke Datiko[4]

[1]Department of Forestry, Ambo University, Ambo, Ethiopia
[2]Department of Natural Resource Management, Ambo University, Ambo, Ethiopia
[3]Department of Natural Resource Management, Madda Walabu University, Robe, Ethiopia
[4]Ethiopian Biodiversity Institute, Hawassa Biodiversity Center, Hawassa, Ethiopia
Email: *gonfa.kewessa@gmail.com

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Abstract

Forest coffee areas are hotspots areas for conservation of biodiversity due to anthropogenic effect on diversity and abundance of indigenous species. This study was aimed to determine the effect of forest coffee management on woody species diversity and composition. The study was conducted in Dellomena and Harenna Buluk districts where natural forest and forest coffee are found adjacently. Systematic sampling method was used to collect woody species data from 16 transect lines. Eighty (80) sample quadrats of 20 m × 20 m quadrat size for mature trees/shrubs and five 5 m × 5 m subplots within each quadrat for saplings and seedlings were used. Forty-seven species of 29 families and 39 species of 24 families were recorded in natural forest and forest coffee areas respectively. Woody species frequently recorded in most of the sample plots were *Celtis africana* (100%), *Podocarpus falcatus* (95%), *Strychnos mitis* (95%), *Diospyros mespiliformis* (95%) *and Diospyros abyssinica* (90%) in the natural forest, and *Celtis africana* (95%) and *Podocarpus falcatus* (95%) in the forest coffee. Woody species richness (P = 0.000), Shannon diversity (P = 0.000), Simpson diversity indices (P = 0.02) and dominance (P = 0.02) were significantly varied between the two forests. This findings revealed significantly higher woody species diversity and richness in natural forest than forest coffee. Negative effects were noticed due to coffee management practices on woody species diversity and composition in forest coffee areas. Hence, reducing the human pressure on forest coffee via awareness raising and training on the effect of coffee management activities and introduction of environmentally friendly forest coffee management techniques are crucial to maintain ecological service and economic benefit of the forest coffee.

Keywords

Biodiversity Conservation, Deforestation, Forest Management, Woody Species Richness

1. Introduction

Worldwide significant number of people have encroached natural forests or protected areas to improve their livelihood. Global forest resources in the tropical areas have decreased much over the last century (Priess et al., 2007). Tropical forests are among species-rich ecosystems that have been negatively influenced at very high rates (Myers, 2000). Tropical forest ecosystem comprises diverse fauna and flora species. The existence of diverse species of plants delivers resources and serves as a home for all species (Barbier et al., 2008). Degradation and deforestation of tropical forests resulted in decline in global biodiversity (Heywood, 1995). Many forest resources in the globe have been over exploited and resulted in difficulties to enhance and conserve native woody species diversity (Brown & Boutin, 2009; Emmanuel, 2011; Nigatu et al., 2017). Similarly, Ethiopian forest ecosystems are severely threatened by agricultural land expansion, wood exploitation, overgrazing and establishment of new settlements in the forested lands (Good, 2004; Senbeta & Denich, 2006; Motuma et al., 2008). Gole et al. (2002) has also reported deforestation rate of 10,000 ha per year in the coffee growing areas in the Southwest Ethiopia. Expansions of coffee cultivation have also resulted in biodiversity loss in Ethiopia (Anonymous, 2010).

Large forest areas in the Ethiopia are found in the major coffee growing areas, including the Harenna forest in Bale (Gole & Senbeta, 2008). These forest areas have already been globally recognized as hotspot areas for biodiversity conservation (Mittermeier et al., 2005) because of the challenging anthropogenic threats to plant and animal species and their biodiversity composition. According to Valencia (2015), coffee agroforestry may be particularly significant for conserving trees of conservation concern and late-successional stage. The original habitat of forest coffee has been promoted as a means for preserving biodiversity in the tropics (Ambinakudige & Sathish, 2009). Indigenous shade trees for coffee production are very common features in coffee production systems of afromontane rainforests (Gole & Senbeta, 2008). Recent studies on some coffee forests of Ethiopia also showed that coffee forests are rich in plant species diversity (Gole, 2003; Schmitt & Grote, 2006; Senbeta, 2006; Gole et al., 2008). Over 700 plants species were recorded in Bale, Bonga, Sheko and Yayu, which represents about 10% of the countries flora (Gole & Senbeta, 2008).

Despite of socioeconomic and ecological importance, expansion of agricultural land and establishment of coffee plantation in Ethiopia negatively affect forests coffee (Gole & Senbeta, 2008) by destroying and degrading woody plant species (Silva et al., 2008; Laurance, 2010; Mebrat & Gashaw, 2013). Moreover, selective cutting of valuable shade tree species for timber production and reducing shade intensity have also depleted woody plant species from the afromontane rainforests (Perfecto et al., 2005; Yadessa et al., 2008). Moreover, conversion of a forest coffee system into a semi-forest coffee system affects the floristic composition and diversity of plant species (Gole, 2003; Senbeta, 2006; Tesfaye, 2006; Schmitt & Grote, 2006).

In Bale Eco-region, the local communities living in and around the forest mainly derive their livelihoods from forests coffee (Senbeta, 2006). Coffee is grown inside the forest by removing competing undergrowth vegetation and some canopy trees (Teketay, 1999; Gole & Senbeta, 2008). Slashing of understory vegetation and thinning of shade trees are a common practice in forest coffee growing areas of Bale Eco-region. This may affects diversity of woody plant species to the extinction and challenges sustainable management of resources in the forest coffee. The loss of biodiversity and the changing pattern of woody species have necessitated the assessment of woody species diversity (Pant & Samant, 2007; Tolera et al., 2008; Mebrat & Gashaw, 2013).

Many studies determined woody species diversity in undisturbed ecosystems and/or agricultural ecosystems of the world but less attention was given to evaluation of effect of forest coffee management practices on plant species diversity and composition in the global hotspot area for biodiversity conservation (Moguel & Toledo, 1999). Specifically, scanty of information exist about woody species diversity and composition in forest coffee areas of afromontanae forest of tropical Africa (Komar, 2006; Senbeta, 2006; Gole & Senbeta, 2008). Some of the studies conducted in some parts of Ethiopia on coffee management and its impact on woody species include Hundera et al. (2013) and Kumsa et al. (2016). Indeed, this study aimed to determine the effect of forest coffee management on woody species diversity and composition in Harenna forest of Bale Eco-region, Southeastern Ethiopia.

2. Materials and Methods

2.1. Study Area

The study was conducted in Dellomena and Harenna Buluk districts of Bale Eco-region in Southeast Ethiopia (**Figure 1**). The study area is characterized by bimodal rainfall with mean annual rainfall of 850 mm and mean annual temperature of 18˚C (Gole & Senbeta, 2008). It encompasses flatlands; moderately steep rolling hills with valley bottoms and waterways. Harenna forest is the largest montane forest in the study eco-region (Senbeta & Denich, 2006; Gole & Senbeta, 2008). It supports over 300 plant species with many endemic plant species (Senbeta, 2006). The unique floristic composition includes *Podocarpus falcatus*, *Ocotea kenyensis*, *Filicium decipiens and Warburgia ugandensis*. Forest coffee occurs between 1300 and 1850 meter above sea level of Harenna forest and dominated by woody species and the understory coffee plants. Majority of the populations in the two districts are settled in the lower southern edging of the

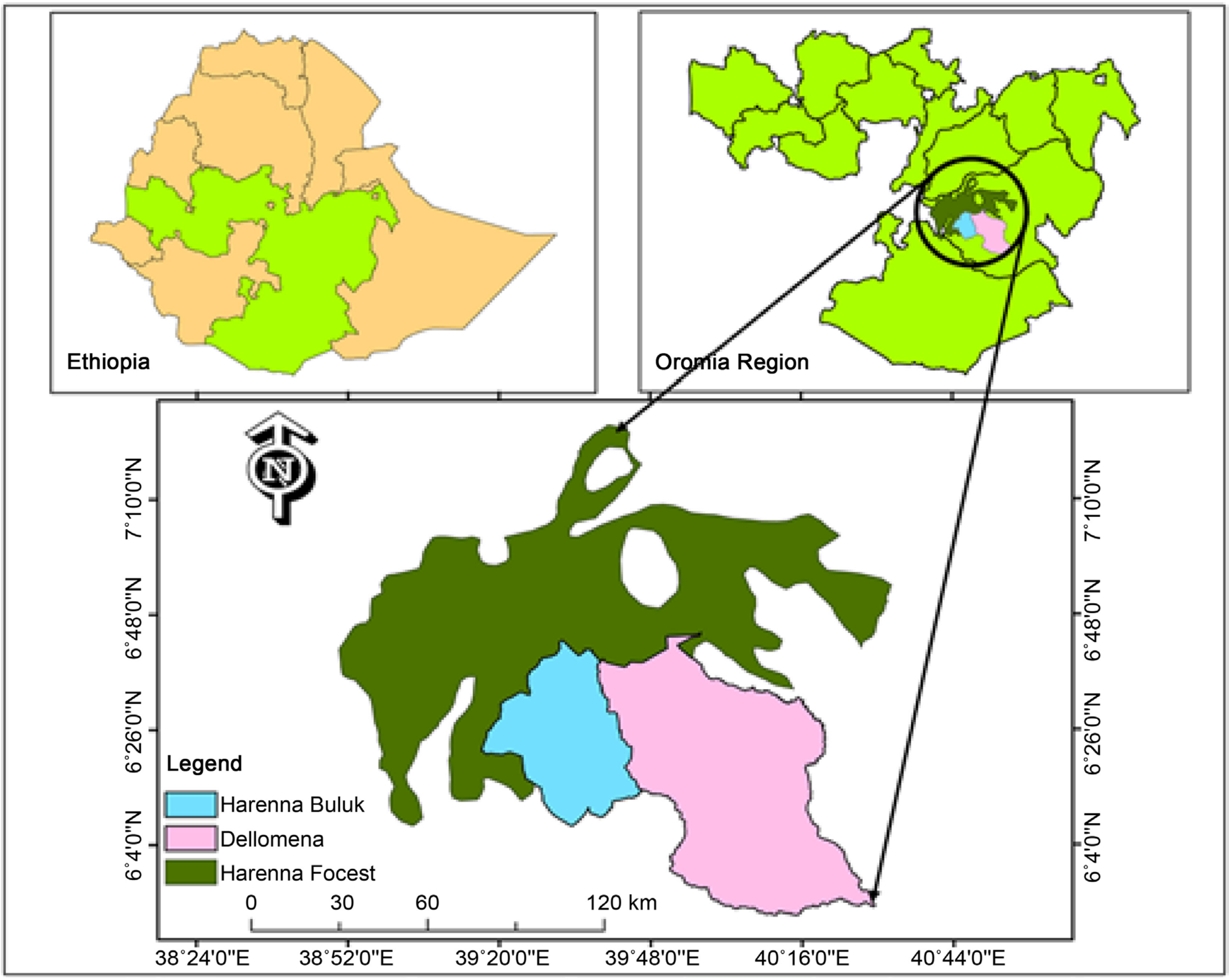

Figure 1. Map of the study area with the map of Ethiopia.

forest and some even in the forest. All people in the study area have coffee plots and beehive, and graze their livestock's in the forest. Their livelihoods mainly depend on forest exploitation, crop and livestock production, and collection of non-timber forest products (Gole & Senbeta, 2008).

2.2. Sampling Techniques

First a reconnaissance survey was made to collect baseline information and to observe vegetation distribution of forests coffee and adjacent natural forest in Harenna Buluk and Dellomena districts. Two sites that encompass both forest coffee and adjacent natural forests were selected purposely from each district. Then, 16 transect lines with 1200 m average length were laid out in both forest coffee and adjacent natural forest. Five main plots of 20 m × 20 m were established on each transect line at interval of 200 m. Forty main plots with a total area of 1.6 ha were established in each forest types to identify woody species. This method was developed in line with Gole (2003). Saplings and seedlings were identified in five subplots of 5 m × 5 m within each main plot for each forest type. Accordingly, 80 main plots (20 m × 20 m) and 400 subplots (5 m × 5 m) were laid in the two forest types with the total area of 3.2 ha. From reconnaissance survey, the total sampled area was assumed to be representative considering that both forest types are under uniform topographical conditions, altitudinal range and woody species distribution.

2.3. Data Collection Methods

Individuals of woody plant species with diameter at breast height (DBH) of larger than 5 cm were identified and counted in the main plots. Saplings (individuals with DBH from 5 to 2.5 cm and height greater than 1 m), and seedlings (individuals with height ≤ 1 m and DBH less than 2.5 cm) were identified and counted within the subplots. Diameter measurements for trees and sapling/seedlings were taken at breast height (1.3 m) and at root collar by using caliper and diameter tape, respectively following (Senbeta & Teketay, 2001). For trees branched below 1.3 m, DBH measurement of each branch was taken independently. Hypsometer and graduated stick were used for height measurements. Geographic location and elevation of each plots was taken using GPS. All woody species in the sample plots were identified by scientific name using the modern *Flora of Ethiopiaand Eritrea* (Friis, 2009). Moreover, forest coffee management practices were identified through transect walk and key informants' interviews. For key informants' interview 12 elderly people who are knowledgeable about the forest resource in the study site were involved.

2.4. Data Analysis

Shannon-Wiener Diversity Index (H') was used to determine floristic composition of forest coffee and adjacent natural forest (Shannon & Weaver, 1948). Evenness or Equitability index (E) was determined to measure of evenness (Krebs, 1999). Species richness was determined by converting the average number of species in forest coffee and adjacent natural forest into hectare bases, and expressed as number of species per hectare. Simpson's diversity index was determined (Magurran, 1988). Sørensen's Similarity Index (β) was used to evaluate floristic similarity between forest coffee and natural forest (Sørensen, 1948). Density of woody plants in each forest types was determined as number of individual per hectare. Then, the variation in woody species richness, dominance, and Simpson, Shannon and Equitability indices between forest coffee and adjacent natural forest was tested by using independent t-test at 95% significance level by using SPSS statistical Software version 20.0.

3. Results and Discussion

3.1. Traditional Forest Coffee Management Practices

Key informants reported that they have collected non-timber forest products like honey, medicinal plants and coffee from the natural forest. However, they have only the right to sell pole of felled trees to Bale Forest and Wildlife Enterprise and utilize for household consumption. As a result, dwellers mainly managed forest coffee areas to increase productivity of coffee plants through slashing of bushes and herbs, thinning of trees through cutting/debarking of stems and cultivation of the land. They also confirmed that lians, herbs, shrubs and trees were cleared from forest coffee areas to reduce the competition of these vegetation with wild coffee plants and to ease management and harvesting of coffee. Similarly, Gole and Senbeta (2008) reported that during opening up phase; small trees, shrubs, and herbaceous vegetation competing with coffee are totally cleared without preferential even for endemic or threatened species. KIs also declared that they slash herbs, tree/shrub seedlings to reduce their competition with understory coffee before the commencement of rainy season and coffee harvesting operation. Moreover, KIs indicated that the productivity of coffee increases as the density of shade trees decrease. This result agrees with Beer et al. (1998), and Faminow and Rodriguez (2001) who revealed that un-shaded systems could produce greater coffee yields. Key informants also reported that they practiced thinning of large trees to allow exposure of coffee plants to solar radiation. However, the canopies of the remaining trees expand, and gradually close up after some years to the level that can highly reduce coffee production. Reduction of shade through killing shade trees is common practice in the forest coffee areas even if it is not allowed legally. Key informants clearly depicted that they gradually cleared other woody plant species and retain only those tree species that they believe to increase coffee productivity. *Cordia africana*, *Croton macrostachyus*, *Millettia ferruginea*, *Ekebergia capensis*, *Podocarpus falcatus*, *Pouteria adolfi-friederici*, *Diospyros abyssinica*, *Olea capensis*, and *Olea welwitschii* are trees species preferred by farmers for coffee shade (Gole & Senbeta, 2008).

It was observed that larger trees were killed furtively as cutting trees is prohibited in forest coffee areas. Key informants declared that most of forest dwellers have killed large trees through debarking of their stem and cutting of their main roots below or at ground level. A key informant amazingly expressed how secretly he killed large trees as "*I dug an elbow pit around a large tree*, *cut its main roots*, *removed barks of the stem*, *returned back the soil into the pit and cover it with partially decomposed organic matter*. *How one can identify what I did*? *Thus*, *the trees seam naturally dead or felled*.". Similarly, Mengist et al. (2013) revealed that cutting tree and tree ringing were practiced in forest coffee of Belete Gera Forest. Hoeing/cultivation is an emerging practice in the forest coffee system to facilitate good rooting condition for coffee plants and to avoid competing understory vegetation. Key informants declared that hoeing was first practiced by illegal settlers in the forest and gradually adopted by others. Key informants also indicated that coffee management activities like hoeing and slashing have negative effects on diversity of woody and non-woody plant species.

3.2. Woody Species Composition

There are 30 families identified in natural forest and forest coffee (**Table 1** and

Table 1. Family and woody plant species in natural forest and forest coffee.

Family	Woody plant species in				Family	Woody plant species in			
	Natural Forest		Forest Coffee			Natural Forest		Forest Coffee	
	No	%	No	%		No	%	No	%
Anacardiaceae	1	2.13	1	2.56	*Meliaceae*	0	0.00	1	2.56
Apocyanceae	1	2.13	0	0.00	*Melianthaceae*	1	2.13	1	2.56
Araliaceae	1	2.13	1	2.56	*Moraceae*	2	4.26	1	2.56
Astraceae	1	2.13	1	2.56	*Myrsinaceae*	1	2.13	0	0.00
Boraginaceae	1	2.13	2	5.13	*Myrtaceae*	2	4.26	1	2.56
Canellaceae	1	2.13	1	2.56	*Oleaceae*	4	8.51	3	7.69
Capparidaceae	1	2.13	0	0.00	*Podocarpaceae*	1	2.13	1	2.56
Celastraceae	1	2.13	0	0.00	*Rhamnaceae*	1	2.13	0	0.00
Combretaceae	1	2.13	1	2.56	*Rhizophoraceae*	1	2.13	1	2.56
Ebenaceae	3	6.38	2	5.13	*Rubiaceae*	4	8.51	4	10.26
Euphorbiaceae	2	4.26	1	2.56	*Rutaceae*	4	8.51	4	10.26
Fabaceae	2	4.26	2	5.13	*Salvadoraceae*	1	2.13	0	0.00
Icacinaceae	1	2.13	1	2.56	*Sapindaceae*	2	4.26	3	7.69
Lauraceae	1	2.13	1	2.56	*Sapotaceae*	1	2.13	1	2.56
Loganiaceae	2	4.26	2	5.13	*Ulmaceae*	2	4.26	2	5.13
Total						**47**	**100**	**39**	**100**

Table 2), respectively. Of which Oleaceae, Rutaceae and Rubiaceae were the plant families that contain large number of woody species in the natural forest, each represented by four species. The Ebenaceae family was represented by three woody species in natural forest. In forest coffee, Rutaceae and Rubiaceae were the dominant families in terms of number of woody species in which each were represented by four species. Oleaceae and Sapindaceae were the next dominant families with three species each in forest coffee. Apocyanceae, Capparidaceae, Celastraceae, Myrsinaceae, Rhamnaceae and Salvadoraceae were families with shrub life forms which were not found in forest coffee areas (**Table 1**). This indicates that shrub species were cleared from forest coffee to reduce competition with coffee plants. Similarly, clearing of shrubs in forest coffee areas was reported in Harenna forest and in Belete Gera Forest (Gole & Senbeta, 2008; Mengist et al., 2013).

Forty-seven woody plant species belonging to 29 families were identified in natural forest (**Table A1**), whereas, 39 woody plant species belonging to 24 families are identified in forest coffee (**Table A2**). *Celtis africana*, *Diospyros mespiliformis*, *Podocarpus falcatus*, *Strychnos mitis*, *Diospyros abyssinica*, *Filicium decipiens*, *Teclea nobilis*, *Cassipourea malosana*, *Galiniera saxifraga* and *Coffea arabica*were frequently observed in the natural forest. In forest coffee, *Coffea arabica*, *Celtis africana*, *Podocarpus falcatus*, *Diospyros mespiliformis*, *Strychnos miti* and *Diospyros abyssinica* were frequently observed woody species. The absolute frequency of *Filicium decipiens*, *Teclea nobilis* and *Olea welwitschii*

Table 2. Woody species composition in natural forest and forest coffee, and their absolute frequency (Note; NF = Natural forest, FC = Forest coffee, NA = Not Available, T = Tree, and TS = Tree or Shrub).

Species Name	Family Name	Local Name	Life form	Absolute Frequency (%)	
				NF	FC
Acalypha volkensii pax	Euphorbiaceae	Fuho	TS	25	NA
Allophylus abyssinicus	Sapindaceae	Arjo	T	NA	10
Apodytes acutifolia	Icacinaceae	Mewa	T	30	5
Avophaylus abyssinica	Sapindaceae	Obora	T	5	5
Bersama abyssinica Fresen.	Melianthaceae	Horoqa	T	15	25
Buddleia polystachya	Loganiaceae	Dhadhatu	T	50	5
Calpurnia aurea (Ait.) Benth.	Fabaceae	Cekata	S	30	15
Capparis tomentosa	Capparidaceae	Arangama	S	20	NA
Carissa spinarum L.	Apocyanceae	Hagamsa	S	20	NA
Cassipourea malosana (Baker) Alston	Rhizophoraceae	Tilo	T	65	45
Celtis africana Burm.f.	Ulmaceae	Mataqoma	T	100	95
Citrus aurantium	Rutaceae	Arbo/Irba	TS	55	20
Coffea arabica L.	Rubiaceae	Buna	S	60	100
Cordia africana Lam.	Boraginaceae	Wadessa	T	NA	5
Crotolaria agatiflora Schweinf. Sub.sp. Erlangeri Bak. F.	Fabaceae	Shashamane	S	10	15
Croton macrostachyus Del.	Euphorbiaceae	Makanisa	T	25	50
Diospyros abyssinica (Hiern) F. White	Ebenaceae	Loko adi	TS	90	80
Diospyros mespiliformis Hochst. Ex A.DC	Ebenaceae	Loko guracha	T	95	85
Dobera glabra	Salvadoraceae	Hara	TS	10	NA
Ehretia cymosa Thonn.	Boraginaceae	Ulaga	T	60	50
Euclea racemosa Murr.subsp. schimperi (A. DC.) White	Ebenaceae	Miesa	T	5	NA
Fagaropsis angolensis (Engl.) Milne	Rutaceae	Sisa	T	15	10
Ficus sur Forssk.	Moraceae	Harbu	T	5	NA
Ficus sycomorus	Moraceae	Lugo	T	NA	5
Ficus thonningii Blume	Moraceae	Dembi	T	5	NA
Filicium decipiens (Wight & Am.) Thw.	Sapindaceae	Cana	T	75	25
Galiniera saxifraga (G. coffeoides)	Rubiaceae	Jaldae	T	65	50
Maytenus gracilipes (Welw.ex Oliv.) Exell subsp. Arguta (Loes.)	Celastraceae	Kombolcha	TS	30	NA
Mimusops kummel A. DC.	Sapotaceae	Qolati	T	20	35
Myrsine africana	Myrsinaceae	Baco/qacama	S	5	NA
Ocotea kenyensis (Chiov.) Robyns & Wilczek	Lauraceae	Gigicha	T	55	25
Olea capensis L. ssp. Macrocarpa (C. H. Wright) Verdc.	Oleaceae	Segida	T	15	NA
Olea capensis subsp. hochstetteri (Bak.) P.S. Friis	Oleaceae	Onoma	T	65	75
Olea welwitschii (Knobl.) Gilg & Schellenb.	Oleaceae	Gagama	T	65	5
Podocarpus falcatus (Thunb.) R. B. ex. Mirb	Podocarpaceae	Birbirsa	T	95	95
Polyscias fulva (Hiern) Harms	Araliaceae	Koriba	T	5	10
Psydrax schimperiana (A. Rich.) Bridson	Rubiaceae	Galo	T	65	55

Continued

Rhamnus prinoides L. Herit.	Rhamnaceae	Gesho	TS	45	NA
Rhus ruspolii Engl.	Anacardiaceae	Hirqe	TS	20	30
Rothmannia urcelliformis (Hiern.) Robyns	Rubiaceae	Bulala	T	60	40
Schrebera alata (Hochst.) Welw.	Oleaceae	Dhamae	T	10	5
Strychnos mitis S. Moore	Loganiceae	Mulka	T	95	85
Strychnos spinosa	Myrtaceae	Gotu	T	5	NA
Syzygium guineense	Myrtaceae	Badessa	T	40	35
Teclea nobilis Del.	Rutaceae	Hadhesa	T	70	25
Terminalia laxilora	Combretaceae	Dabaqa	T	30	15
Trema guineensis (Schumach. & Thonn.)	Ulmaceae	Hagala	T	5	5
Trichilia emetica (T. roka)	Meliaceae	Anonu	T	NA	5
Vepris dainellii (Pichi-Serm.) Kokwaro	Rutaceae	Arabe	TS	60	20
Vernonia leopoldi (Sch. Bip. ex walp.) Vatke	Astraceae	Reji	S	10	15
Warburgia ugandensis Sprague	Canellaceae	Befti	T	60	55

recorded in the adjacent natural forest were reduced from 75% to 25%, 70% to 25% and 65% to 5% in the forest coffee. However, its value increased in the case of *Coffea arabica* and *Croton macrostachyus* from 60% to 100% and from 25 to 50% respectively. This implies that abundance of coffee and some shade tree species were increased by reducing other woody species that thereof affect woody species composition in forest coffee. Similarly, retention or planting of preferable shade tree species and clearance of other species were reported in coffee forest and plantations in different part of the world (Ambinakudige & Sathish, 2009; Mengist et al., 2013; Likassa, 2014).

The species richness of natural forest and forest coffee were 19 ± 0.9 and 12.55 ± 0.73 respectively (**Table 1**). It showed significant difference ($P = 0.001$) between forest coffee and adjacent natural forest. The above results indicate that more woody species were found in adjacent natural forest as compared to the forest coffee. Similarly, research findings of Ambinakudige and Sathish (2009), Hylander and Sileshi (2009) and Likassa (2014) revealed higher tree species diversity in adjacent natural forests than in shade coffee farms. The effect of coffee management practices has affected negatively woody species diversity and richness in the forest coffee. Moreover, local people retained only selected shade trees as over storey trees in the system. Similarly, Wassie et al. (2009) also declared the negative effect human induced disturbance on species diversity in forest coffee.

3.3. Life Form of Woody Species in Forest Coffee and Adjacent Natural Forest

Tree is the dominant life form of woody species in the natural forest and forest coffee. Tree constituted 63.5% and 71.4% of woody species in natural forest and forest coffee, respectively. Shrubs are the co-dominant life form of woody species, which contributes 11.91% and 11.54% in natural and forest coffee, respectively. This greater percentage of tree life form in forest coffee is due to retention of shade trees in the system.

3.4. Woody Species Diversity

The Simpson diversity index of 0.84 ± 0.012 and 0.74 ± 0.039, and Shannon diversity index of 2.15 ± 0.072 and 1.74 ± 0.098 were obtained in natural forest and forest coffee respectively (**Table 3**). Similarly, Mengist et al. (2013) found higher Shannon diversity index in forest without coffee (2.98) than in the forest with coffee (2.13). Senbeta and Denich (2006) found higher Shannon diversity index of 2.82 and 2.6 at Bebeka forest coffee and Harenna forest coffee respectively. Both Simpson ($P = 0.02$) and Shannon ($P = 0.00$) have significant higher value in natural forest than forest coffee in this study. These indicate that coffee management practices resulted in lower woody species diversity in forest coffee. Similarly, Engida and Teshome (2012) revealed that forests with low levels of disturbance have high species diversity as compared to disturbed forest. The above results imply that management of coffee forests has affected and will continue to affect the diversity of woody species in the forests. Similarly, Kufa (2006) reported that as coffee management continues, the coffee forest could be changed to coffee farms with a few shade trees.

Dominance of 0.26 ± 0.039 and 0.16 ± 0.012 were recorded in the forest coffee and adjacent natural forest respectively. The significantly ($P = 0.02$) higher value of dominance in forest coffee indicated presence of large number of individuals of few species. This variation in dominance may come from different management intervention undertaken in forest coffee like slashing, hoeing, weeding and human interferences. Similarly, Wassie et al. (2009) and Mekuria and Aynekulu (2011) indicated that human induced disturbance have a strong negative effect on species composition, seed germination, seedling growth, and mortality of many of the plant communities and in turn results in less species richness. Schmitt et al. (2009) also indicated that management interventions in semi-forest coffee shown a strong impact on tree species composition. Moreover, Walters et al. (2006) indicated that land use change affects the composition, diversity and distribution pattern of vegetation. Species equitability/evenness indices of natural forest and coffee forest were 0.73 ± 0.02 and 0.69 ± 0.04 respectively (**Table 3**). This indicates that about 70% of woody species are equally

Table 3. Woody species diversity indices in natural forest and forest coffee.

Land use	Diversity parameters				
	Richness	Dominance	Simpson	Shannon	Equitability
Natural forest	19 ± 0.9	0.16 ± 0.012	0.84 ± 0.012	2.15 ± 0.072	0.73 ± 0.02
Forest coffee	12.55 ± 0.73	0.26 ± 0.039	0.74 ± 0.039	1.74 ± 0.098	0.69 ± 0.04
P-value	0.000	0.02	0.02	0.000	0.27

available and distributed in both natural forest and forest coffee. Wilson et al. (1996) also revealed that a higher value of evenness indicates that most species are present with relatively equal individuals in a community. Moreover, Magurran (2004) indicated that the evenness measure of 1 revealed being complete evenness in a community.

3.5. Variation in Woody Species Composition between Natural Forest and Forest Coffee

Sørensen's similarity index of 0.814 was found for natural forest and forest coffee. This implies that more woody species overlap between the two ecosystems. Similarly, Sørensen (1948) revealed that Sørensen's similarity index of 0 indicates there is no species overlap between the communities and a value of 1 indicates exactly the same species are found in both communities. The finding of this study also agrees with the findings of Hylander and Sileshi (2009) and contradicts with the finding of Mendez et al. (2007).

Of 51 woody species identified in both forest types, 35 species (68.6%) were common to both forest types. However, 12 (23.5%) and 4 (7.9%) were unique to the natural forest and forest coffee respectively. This implies natural forest contains comparatively more unique woody species than the adjacent forest coffee. This agrees with the results of Likassa (2014) which reported presence of more unique species in natural forest as compared to forest coffee.

3.6. Occurrence Frequency of Woody Species

Frequency of occurrence of the species across sample plots varies between natural forest and forest coffee (**Figure 2** and **Figure 3**). Five species in the natural forest and two species in forest coffee had an absolute frequency greater than 90%. Those species in natural forest include *Celtis africana* (100%), *Podocarpus*

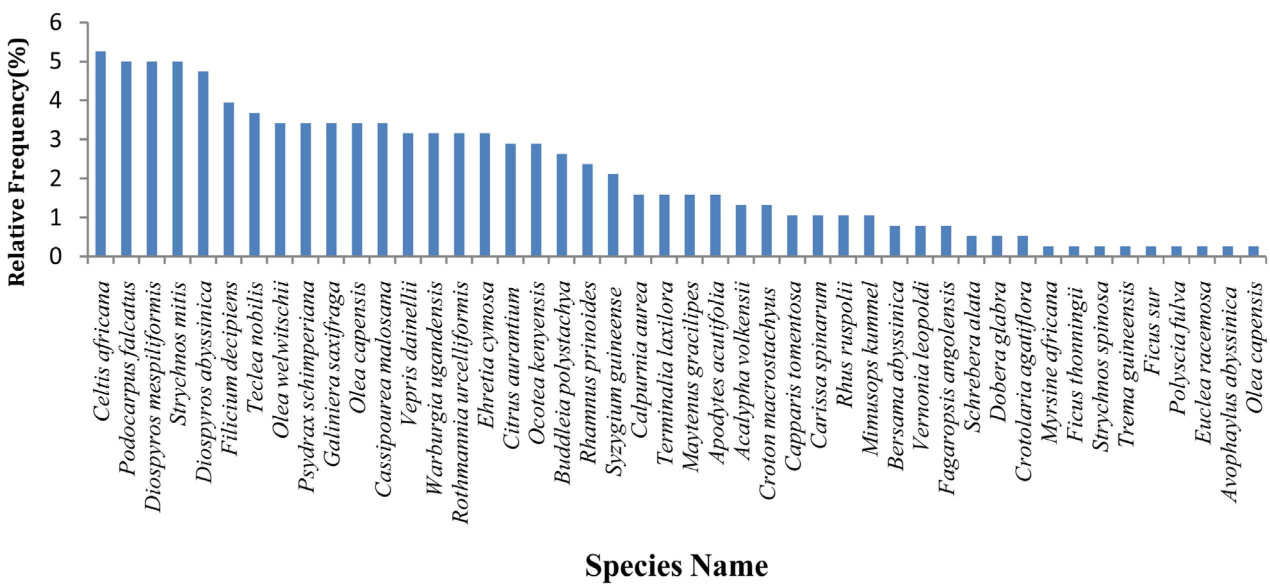

Figure 2. Frequency of woody species natural forest.

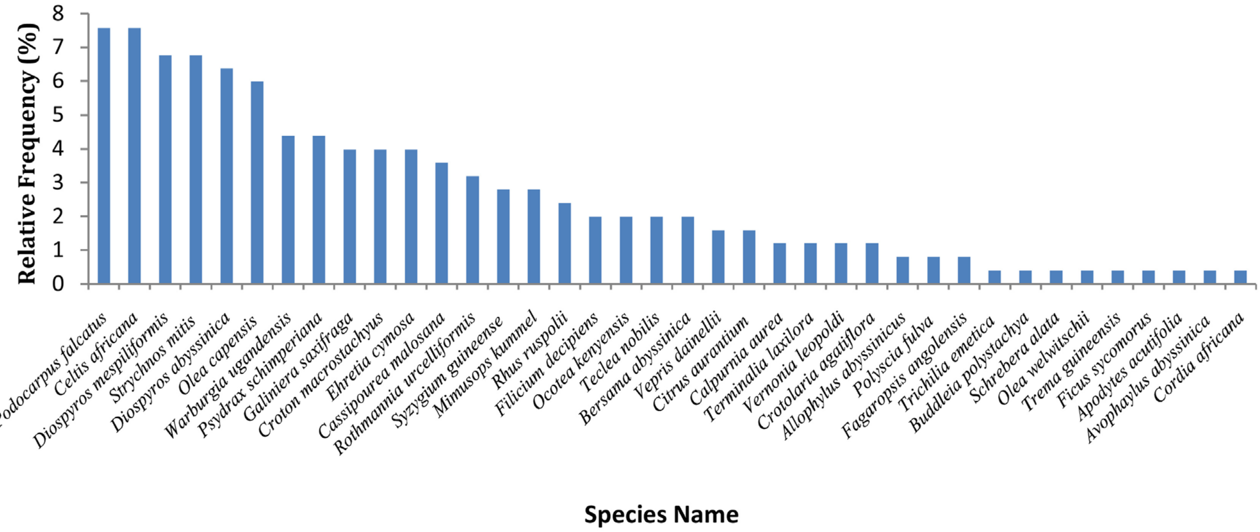

Figure 3. Frequency of woody species forest coffee.

falcatus (95%), *Strychnos mitis* (95%), *Diospyros mespiliformis* (95%) *and Diospyros abyssinica* (90%) while those of forest coffee includes *Celtis africana* (95%) and *Podocarpus falcatus* (95%). Furthermore, 20 species in the natural forest and 11 in the forest coffee were occurred in more than half (50%) of the total plots investigated. This implies that large number of species were recorded in few quadrats.

Smaller number of tree species frequently observed in forest coffee as compared to the adjacent natural forest. This is due to, the traditional management of shade tree in Ethiopia is to reduce tree density and understory vegetation to improve the production of coffee while maximizing the use of selected tree species (Aerts et al. 2011). Farmers selectively remove some tree species through various management techniques, including selection of tree species with desirable properties (Asfaw, 2003; Abebaw, 2006). For this reason, only few shade tree species with a greater economic or ecological value (shade) or both dominated the coffee-based forest system in the Harenna forest.

4. Conclusion

Dellomena and Harenna Buluq districts of Bale Eco-region endowed large area of forest coffee. The livelihoods of most of peoples in the districts are largely dependent on forest coffee. Local communities have practiced slashing understory vegetation, thinning of large trees and hoeing in forest coffee areas to improve productivity of coffee plants. As a result, woody species richness, Shannon diversity, Simpson diversity indices and dominance were significantly varied between the two forests. These findings revealed significantly higher woody species diversity and richness in natural forest than forest coffee. These results could confirm that coffee management practices have significantly reduced composition, diversity and evenness of woody species in forest coffee. Negative effects were noticed due to coffee management practices on woody species diversity and composition in forest coffee areas. This maximization of productivity of coffee in expense of the indigenous woody species might silently eradicate the remnant Afromontane forest and biodiversity in the study area if not timely and well addressed. Therefore, it is compulsory to maximize the benefit of growing population from forest coffee through introducing compatible alternative income sources like modern honeybee production and others that minimize reliance on coffee in a way that it can balance conservation and utilization of natural resources. To this end, reducing the human pressure on forest coffee via awareness raising and training on the effect of coffee management activities and introduction of environmentally friendly forest coffee management techniques are crucial to maintain ecological service and economic benefit of the forest coffee.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Appendices

Table A1. Woody species composition of natural forest in the study site (T = Tree, TS = Tree/Shrub).

No.	Species Name	Family Name	Local Name	Life form	Absolute Frequency
1.	*Acalypha volkensii pax*	Euphorbiaceae	Fuho	TS	25
2.	Apodytes acutifolia	Icacinaceae	Mewa	T	30
3.	*Avophaylus abyssinica*	Sapindaceae	Obora	T	5
4.	*Bersama abyssinica Fresen.*	Melianthaceae	Horoqa	T	15
5.	*Buddleia polystachya*	Loganiaceae	Dhadhatu	T	50
6.	*Calpurnia aurea* (*Ait.*) *Benth.*	Fabaceae	Cekata	S	30
7.	*Capparis tomentosa*	Capparidaceae	Arangama	S	20
8.	*Carissa spinarum* L.	Apocyanceae	Hagamsa	S	20
9.	*Cassipourea malosana* (*Baker*) *Alston*	Rhizophoraceae	Tilo	T	65
10.	*Celtis africana Burm.f.*	Ulmaceae	Mataqoma	T	100
11.	*Citrus aurantium*	Rutaceae	Arbo/Irba	TS	55
12.	*Coffea arabica L.*	Rubiaceae	Buna	S	60
13.	*Crotolaria agatiflora Schweinf. Sub.sp. Erlangeri Bak. F.*	Fabaceae	Shashamane	S	10
14.	*Croton macrostachyus Del.*	Euphorbiaceae	Makanisa	T	25
15.	*Diospyros abyssinica* (*Hiern*) *F. White*	Ebenaceae	Loko adi	TS	90
16.	*Diospyros mespiliformis Hochst. Ex A.DC*	Ebenaceae	Loko guracha	T	95
17.	*Dobera glabra*	Salvadoraceae	Hara	TS	10
18.	*Ehretia cymosa Thonn.*	Boraginaceae	Ulaga	T	60
19.	*Euclea racemosa Murr.subsp. schimperi* (*A. DC.*) *White*	Ebenaceae	Miesa	T	5
20.	*Fagaropsis angolensis* (*Engl.*) *Milne*	Rutaceae	Sisa	T	15
21.	*Ficus sur* Forssk.	Moraceae	Harbu	T	5
22.	*Ficus thonningii* Blume	Moraceae	Dembi	T	5
23.	*Filicium decipiens* (*Wight* & *Am.*) *Thw.*	Sapindaceae	Cana	T	75
24.	*Galiniera saxifraga* (*G. coffeoides*)	Rubiaceae	Jaldae	T	65
25.	*Maytenus gracilipes* (*Welw.ex Oliv.*) *Exell subsp. Arguta* (*Loes.*)	Celastraceae	Kombolcha	TS	30
26.	*Mimusops kummel A. DC.*	Sapotaceae	Qolati	T	20
27.	*Myrsine africana*	Myrsinaceae	Baco/qacama	S	5
28.	*Ocotea kenyensis* (*Chiov.*) *Robyns & Wilczek*	Lauraceae	Gigicha	T	55
29.	*Olea capensis L. ssp. Macrocarpa* (*C. H. Wright*) *Verdc.*	Oleaceae	Segida	T	15
30.	*Olea capensis subsp. hochstetteri* (*Bak.*) *P.S. Friis*	Oleaceae	Onoma	T	65
31.	*Olea welwitschii* (*Knobl.*) *Gilg & Schellenb.*	Oleaceae	Gagama	T	65
32.	*Podocarpus falcatus* (*Thunb.*) *R. B. ex. Mirb*	Podocarpaceae	Birbirsa	T	95
33.	*Polyscias fulva* (*Hiern*) *Harms*	Araliaceae	Koriba	T	5
34.	*Psydrax schimperiana* (*A. Rich.*) *Bridson*	Rubiaceae	Galo	T	65
35.	*Rhamnus prinoides L. Herit.*	Rhamnaceae	Gesho	TS	45
36.	*Rhus ruspo*lii Engl.	Anacardiaceae	Hirqe	TS	20
37.	*Rothmannia urcelliformis* (*Hiern.*) *Robyns*	Rubiaceae	Bulala	T	60
38.	*Schrebera alata* (*Hochst.*) *Welw.*	Oleaceae	Dhamae	T	10
39.	*Strychnos mitis S. Moore*	Loganiceae	Mulka	T	95
40.	*Strychnos spinosa*	Myrtaceae	Gotu	T	5
41.	*Syzygium guineense*	Myrtaceae	Badessa	T	40
42.	*Teclea nobilis Del.*	Rutaceae	Hadhesa	T	70
43.	*Terminalia laxilora*	Combretaceae	Dabaqa	T	30
44.	*Trema guineensis* (*Schumach.* & *Thonn.*)	Ulmaceae	Hagala	T	5
45.	*Vepris dainellii* (Pichi-Serm.) Kokwaro	Rutaceae	Arabe	TS	60
46.	*Vernonia leopoldi* (*Sch. Bip. ex walp.*) Vatke	Astraceae	Reji	S	10
47.	*Warburgia ugandensis Sprague*	Canellaceae	Befti	T	60

Table A2. Woody species composition of forest coffee in the study site (T = Tree, TS = Tree/Shrub).

No.	Species Name	Family Name	Local Name	Life form	Absolute Frequency
1.	*Allophylus abyssinicus*	Sapindaceae	Arjo	T	10
2.	*Apodytes acutifolia*	Icacinaceae	Mewa	T	5
3.	*Avophaylus abyssinica*	Sapindaceae	Obora	T	5
4.	*Bersama abyssinica Fresen.*	Melianthaceae	Horoqa	S	25
5.	*Buddleia polystachya*	Loganiaceae	Dhadhatu	T	5
6.	*Calpurnia aurea (Ait.) Benth.*	Fabaceae	Cekata	S	15
7.	*Cassipourea malosana (Baker) Alston*	Rhizophoraceae	Tilo	T	45
8.	*Celtis africana Burm.f.*	Ulmaceae	Mataqoma	T	95
9.	*Citrus aurantium*	Rutaceae	Arbo/Irba	TS	20
10.	*Coffea arabica L.*	Rubiaceae	Buna	S	100
11.	*Cordia africana Lam.*	Boraginaceae	Wadessa	T	5
12.	*Crotolaria agatiflora Schweinf. Sub.sp. Erlangeri Bak. F.*	Fabaceae	Shashamane	S	15
13.	*Croton macrostachyus Del.*	Euphorbiaceae	Makanisa	T	50
14.	*Diospyros abyssinica (Hiern) F. White*	Ebenaceae	Loko adi	TS	80
15.	*Diospyros mespiliformis Hochst. Ex A.DC*	Ebenaceae	Loko guracha	T	85
16.	*Ehretia cymosa Thonn.*	Boraginaceae	Ulaga	T	50
17.	*Fagaropsis angolensis (Engl.) Milne*	Rutaceae	Sisa	T	10
18.	*Ficus sycomorus*	Moraceae	Lugo	T	5
19.	*Filicium decipiens (Wight & Am.) Thw.*	Sapindaceae	Cana	T	25
20.	*Galiniera saxifraga (G. coffeoides)*	Rubiaceae	Jaldae	T	50
21.	*Mimusops kummel A. DC.*	Sapotaceae	Qolati	T	35
22.	*Ocotea kenyensis (Chiov.) Robyns & Wilczek*	Lauraceae	Gigicha	T	25
23.	*Olea capensis subsp.hochstetteri (Bak.) P.S. Friis*	Oleaceae	Onoma	T	75
24.	*Olea welwitschii (Knobl.) Gilg & Schellenb.*	Oleaceae	Gagama	T	5
25.	*Podocarpus falcatus (Thunb.) R. B. ex. Mirb*	Podocarpaceae	Birbirsa	T	95
26.	*Polyscias fulva (Hiern) Harms*	Araliaceae	Koriba	T	10
27.	*Psydrax schimperiana (A. Rich.) Bridson*	Rubiaceae	Galo	T	55
28.	*Rhus ruspolii Engl.*	Anacardiaceae	Hirqe	TS	30
29.	*Rothmannia urcelliformis (Hiern.) Robyns*	Rubiaceae	Bulala	T	40
30.	*Schrebera alata (Hochst.) Welw.*	Oleaceae	Dhamae	T	5
31.	*Strychnos mitis S. Moore*	Loganiceae	Mulka	T	85
32.	*Syzygium guineense*	Myrtaceae	Badessa	T	35
33.	*Teclea nobilis Del.*	Rutaceae	Hadhesa	T	25
34.	*Terminalia laxilora*	Combretaceae	Dabaqa	T	15
35.	*Trema guineensis (Schumach. & Thonn.) Ficalho*	Ulmaceae	Hagala	T	5
36.	*Trichilia emetica (T. roka)*	Meliaceae	Anonu	T	5
37.	*Vepris dainellii (Pichi-Serm.) Kokwaro*	Rutaceae	Arabe	TS	20
38.	*Vernonia leopoldi (Sch. Bip. ex walp.) Vatke*	Astraceae	Reji	S	15
39.	*Warburgia ugandensis Sprague*	Canellaceae	Befti	T	55